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7 App. Mil. 65[±]

Reports

REPORTS OF THE

STRENGTH AND OTHER PROPERTIES

METALS FOR CANNON

PREPARED BY THE BUREAU OF THE ARMY, AND OF THE
COMMISSIONERS OF THE ARMY AND NAVY

OFFICE OF THE SECRETARY OF THE ARMY

WASHINGTON, D. C.

1877

NO. 1000

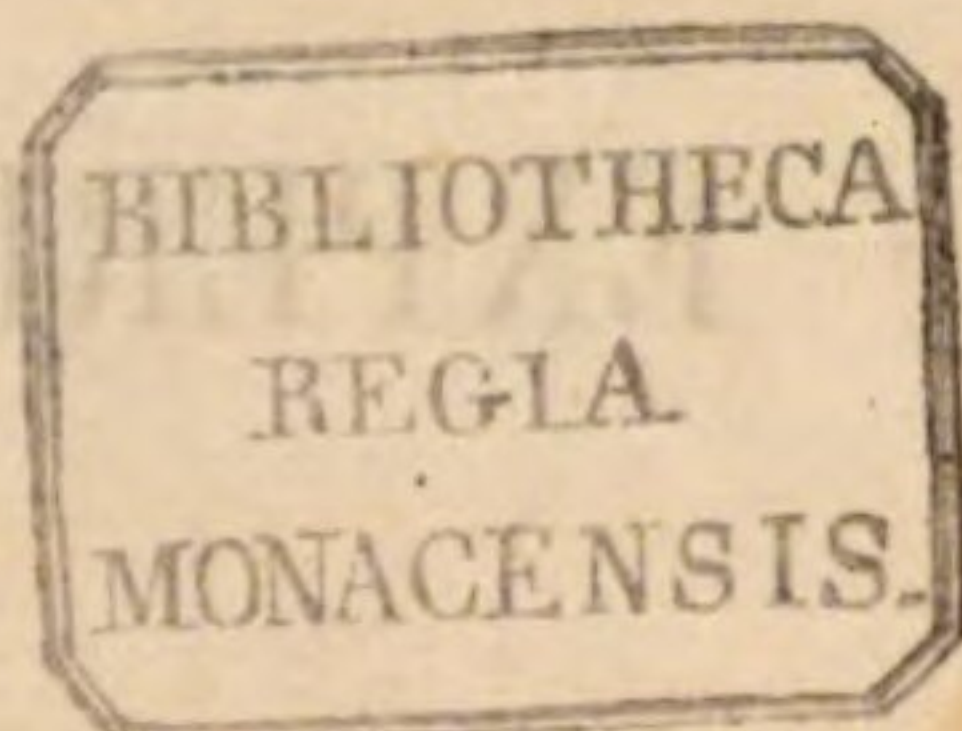
REPORTS OF EXPERIMENTS
ON THE
STRENGTH AND OTHER PROPERTIES
OF
METALS FOR CANNON.

WITH A
DESCRIPTION OF THE MACHINES FOR TESTING METALS, AND OF THE
CLASSIFICATION OF CANNON IN SERVICE.

BY
OFFICERS OF THE ORDNANCE DEPARTMENT,
U. S. ARMY.

By Authority of the Secretary of War.

PHILADELPHIA:
HENRY CAREY BAIRD,
SUCCESSOR TO E. L. CAREY.
1856.



P R E F A C E.

THE following Reports made by Officers of this Department during the last few years, containing much information of general as well as professional value upon the subject of Cannon, and Metals used in their fabrication, are now collected and published.

The Orders for undertaking these investigations were given (soon after the present organization of the Ordnance Corps), in order to procure information required in the Arrangement and Improvement of our system of "Military Munitions" and "Artillery for the Land Service."

The "Ordnance Manual of 1840," contained the results of the first labors of the Ordnance Corps to this end. A minute description of all the details of Form and Construction of all Ordnance and Ordnance Stores, to be supplied to the Army, was there given according to the best patterns then known, but the patterns and material of our Cannon therein prescribed, although regarded as the best that could be then adopted, were known to require much further improvement. In durability and economy Cast Iron is the best material known for Cannon, but past experience had shown such different results in the endurance of Cast Iron Cannon, that it was evident no sufficient reliance could be placed upon the Guns then in Service, nor upon those daily manufactured for the Government. Some of these Guns had been severely tested, and endured without apparent injury more than 2000 rounds, but others, ordered to be made exactly like them in every particular, frequently failed to bear even the proof charges, or burst after a few rounds in Service. Their failure was not therefore due to the material, but because the Founders were not familiar with the variety of metal best suited for the manufacture of Cannon, nor with its proper treatment during that process. It was known that the varieties of the Ore were almost innumerable, and that they differed from each other by almost imper-

ceptible shades; but which were of advantage, and which injurious to Gun Metal, could only be decided by long and careful investigation, which no individual establishment could conduct. A careful study by Officers of the Corps, of the processes pursued at the best Foundries in Europe, and a comparative trial of Pattern Guns cast at several of them, with like guns cast at our own Foundries, only confirmed our previous experience as to the necessity of a more complete investigation of the nature of Iron Ore, and its proper treatment, before it could be used with safety for Guns; and, especially, for those of weights suitable for Field Service.

Under these circumstances, as the best present resource, it was decided to use Cast Iron for the heavy Sea Coast, Siege, and Garrison Cannon only, and to adopt Bronze—a material not liable to burst into fragments—for the lighter class of Guns for use in the Field. Trial Bronze Guns of the best form for our use, were at once made at different Foundries, and subjected to comparative proof. After a careful analysis of the material, patterns were established, and their manufacture commenced under regulations which have thus far secured us Field Guns of good quality and uniform endurance. Improved patterns of Cast Iron Heavy Cannon were also adopted for present use; and complete Drawings, showing the form and dimensions of everything appertaining to the “Artillery for the Land Service,” with the necessary volume of Text, were subsequently published.

At the same time, stringent and explicit Regulations were prescribed, for the service at the Foundries casting Cannon for the Government,—to be enforced under the responsibility of an Officer attending;—and the “Superintending Officer at the Foundries” was directed to make a thorough investigation of the qualities of Cast Iron and Bronze; to test the Ores and Guns in every stage to completion; to devise proper Tests and Processes for general use, and the Means and Machines for applying them. It was expected that by thus following minutely the same well digested plan at all the Foundries, in connection with a regular system of experiments upon the qualities of the metals, experience would soon detect many previous errors and establish a course, at each Foundry, the most proper to produce the best results. These Reports show how much has been effected in this direction.

In order to classify the Iron Cannon then on hand, so that the best only should be used in service, another Officer was directed to devise a system of Mechanical Tests, to be applied to specimens taken from each gun (with-

out injury to its serviceable qualities) and to arrange all, *comparatively as to probable endurance*, in three Classes; *doubtful* and *bad* Guns to be marked *two* and *three*, and to be reserved from issue. To test this Classification, sample guns of each Class were afterwards collected at Fort Monroe, and there proved to extremity, by firing according to an established series; and, to further assist in these researches, a Chemical Analysis was made of certain specimens from each of the Classes, to detect if possible the exact constituents of each variety of Gun Metal, and to note how these agreed with the other tests for Classification.

The Reports of these Officers, together with one on a new plan, proposed by an Officer of the Ordnance Corps, for improving the quality of heavy Iron Castings, constitute the series included in this Publication.

H. K. CRAIG,

Col. of Ordnance.

ORDNANCE OFFICE WASHINGTON, November, 1855.

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REPORT

OF

EXPERIMENTS

IN THE MANUFACTURE AND EXTREME PROOF
OF 6 PDR. IRON CANNON.

MARCH, 1844.

REPORT

OF THE

MANUFACTURE AND PROOF OF 6 PDR. IRON CANNON CAST AT THE SOUTH BOSTON FOUNDRY: 1844.

FOUR 6 pdr. iron cannon were cast February 5th, all from iron of the same kind, and of the same melting, but at different periods of time after fusion; the purpose of the experiment being to ascertain, in what manner the quality of the iron was affected by its continuance in fusion, exposed to intense heat, for longer or shorter periods of time, before casting; and to determine how far this process should be extended, in order to produce the best effect.

The iron used, was made at the Franklin Smelting Furnace, New Jersey. The furnace was charged with 10,000 pounds, one-half of which consisted of iron which had been prepared by remelting, and had been continued in fusion three and a half hours, and then cast into pigs; the other half consisted of fresh pigs, as they were when delivered from the smelting furnace. The furnace was charged before the fire was lighted, and the time occupied in melting the iron was three and a half hours. The guns were cast in the following order:—

No. 1.—Directly after the iron was melted.

No. 2.—After the iron had been in fusion one hour.

No. 3.—After it had been in fusion two hours; and

No. 4.—After it had been in fusion three hours.

The melting and casting on this occasion were not of a satisfactory character. The furnace did not work well; the requisite heat could not be obtained; the melted iron came from it with a lower temperature, and with less fluidity than usual, and not in that free liquid form deemed essential

for perfect castings. Two of the guns, Nos. 1 and 4, were found to be unsound, containing many cavities on the exterior, and within the bore, some of them more than one inch diameter. In casting No. 4, the melted iron fell short in quantity, and did not fill the mould. The deficiency was supplied from a cupola furnace of common iron, designed for ordinary foundry castings. This cupola iron, supplied from 12 to 15 inches of the upper part of the gun, in addition to the sinking head.

The imperfections were so manifest and extensive, that the castings would have been rejected at once, without boring, if they had been designed for ordinary service. As the trials of them might, however, furnish some useful information, they were bored and proved. But, as the results obtained from such imperfect guns could not be satisfactory or conclusive, it was determined to proceed, in the mean time, to cast another parcel.

A drawing of these guns is annexed (Plate 1, Fig. 1), by which it will be seen, that the length and weight are the same as the bronze guns of the established model; and that the form is different. The iron guns have a greater thickness of metal in that part which surrounds the cartridge, and a corresponding reduction is made at, and near, the muzzle.

In arranging a system of proof charges, it was thought best to adopt a plan which would give a gradually increasing force, at each successive fire, from the first charge up to some suitable maximum, and then to continue the latter until the gun should burst; also, that the proof charges should strain the gun, as nearly as practicable, in that part, which is most severely strained by ordinary service charges. As the greatest force produced by any charge, is exerted upon that part of the bore which is situated between the centre of the first ball and bottom of the bore, it was thought best to use moderately small cartridges, and to augment the force of the charge by the addition of balls.

Cartridges containing two pounds of powder were at first adopted; but, on finding that these did not give a sufficient force for a convenient maximum charge, the quantity was increased to two and a half pounds, and afterwards, to three pounds; the latter, with as many balls as the gun would contain, constituting the maximum charge, to be continued as long as a gun might endure.

The cartridges are made with hemispherical bottoms, and closed at the top by thin, cylindrical blocks.

6 Pdr. Gun.

No 2.



Fig 3



for perfect castings. Two of the guns, Nos. 1 and 4, were found to be unsound, containing many cavities on the exterior, and within the bore, some of them more than one inch diameter. In casting No. 2, the melted iron fell short in quantity, and did not fill the mould. The deficiency was supplied from a cupola furnace of common iron, designed for ordinary foundry castings. This cupola iron, supplied from 12 to 13 inches of the upper part of the gun, in addition to the sinking head.

The imperfections were so manifest and extensive, that the castings would have been rejected at once, without boring, if they had been intended for ordinary service. As the trials of them might, however, furnish some useful information, they were bored and proved. But, as the results observed on such imperfect guns could not be satisfactory or conclusive, it was determined to proceed, in the mean time, to cast another parcel.

A drawing of three guns is annexed (Plate I, Fig. 1), by which it may be seen, that the length and weight are the same as the bronze guns of the established model; and that the form is different. The iron guns have a greater thickness of metal in that part which surrounds the cartridges, and a corresponding reduction is made at, and near, the muzzle.

In arranging a system of proof charges, it was thought best to adopt a plan which would give a gradually increasing force, at each successive charge, from the first charge up to some suitable maximum, and then to repeat the latter until the gun should burst; also, that the proof charges should strain the gun, as nearly as practicable, in that part, which is most severely strained by ordinary service charges. As the greatest force produced by any charge, is exerted upon that part of the bore which is situated between the centre of the first ball and bottom of the bore, it was thought best to use moderately small cartridges, and to augment the force of the charge by the addition of balls.

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The cartridges are made with hemispherical bottoms, and closed at the top by thin, cylindrical blocks.

6 Pdr. Gun.

Fig. 1.

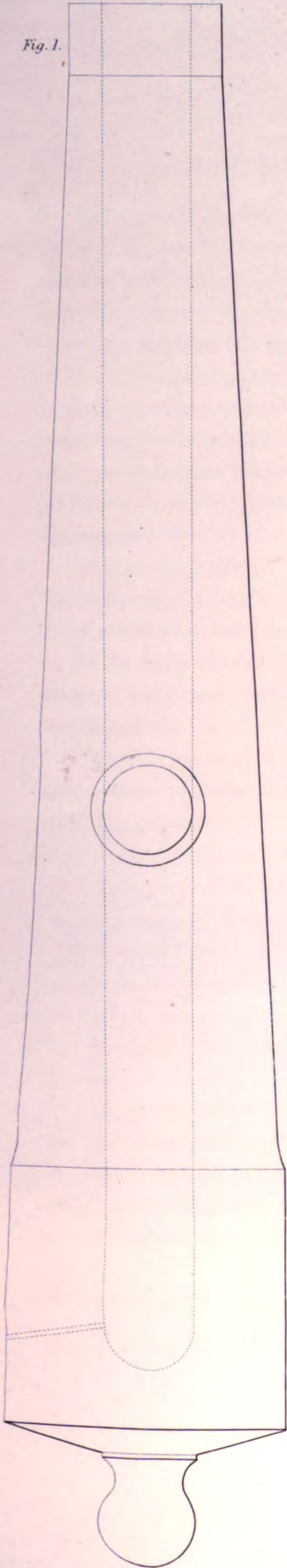


Fig. 2.

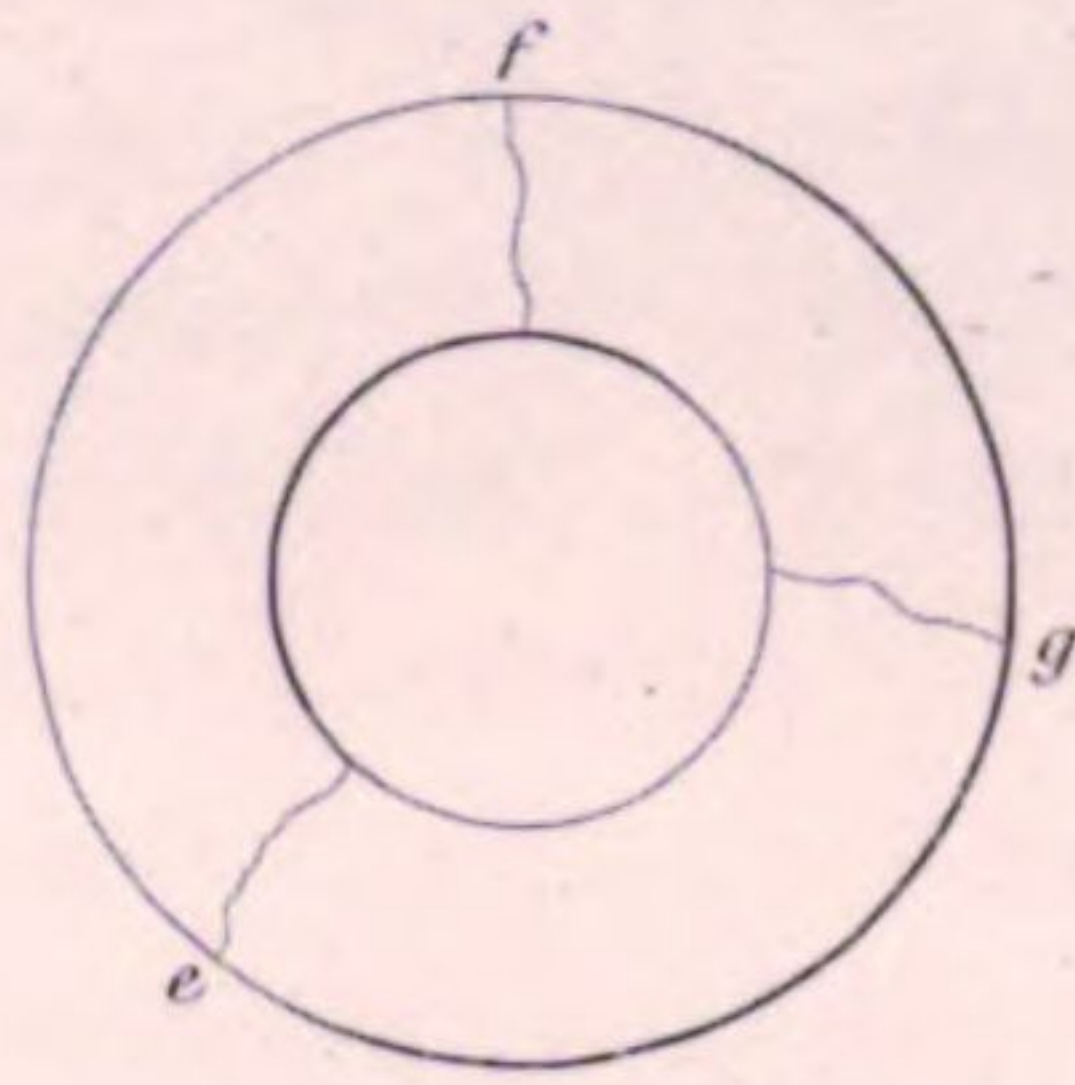
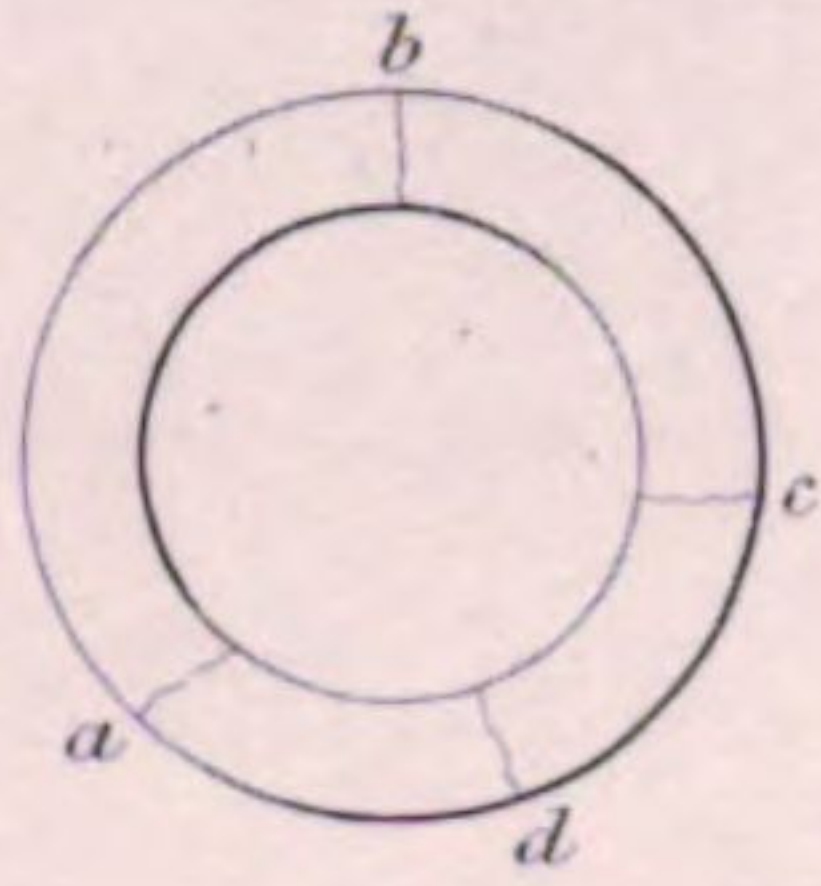
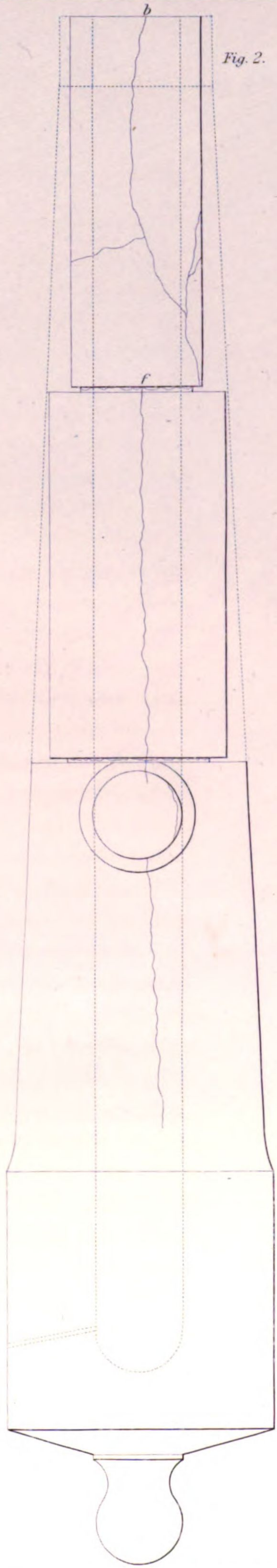
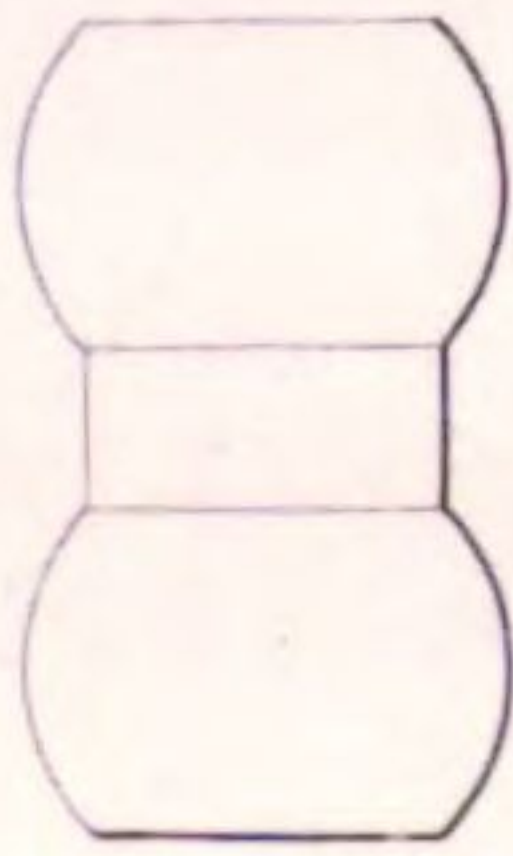


Fig. 3.



Scale $\frac{1}{6}$.

In former trials with high charges, it was found that the common round balls used, were frequently crushed and wedged within the bore of the gun ; thereby developing unequal and greater forces than is caused by the weight of the projectile. To remove this cause of uncertainty in the results, the balls were cast in pairs, the two balls being connected by a cylinder, the diameter of which is equal to three-fourths the diameter of the balls. The ends of the pair are planes perpendicular to the axis, and of the same diameter as the connecting cylinder (Plate 1, Fig. 3). The windage and the weight of the pair, are the same as of two spherical balls. They occupy less space in the gun than an equal number of round balls, so that a greater number of the former may be used in a maximum proof charge.

This method of casting the balls in pairs, has proved entirely successful. No instance of their having been crushed within the gun, has been discovered since they were first used.

With balls of this form, no wads are necessary. For this reason, and because wads cause an uncertain amount of resistance, none have been used in these trials.

The following table exhibits the order of firing, the quantity of powder, and number of balls, used in each charge, from the beginning of the firing until the guns burst.

Proof Charges of 6-pdr. Guns. February 23, 1844.

Order of firing.	Pounds of powder.	Number of balls.	Order of firing.	Pounds of powder.	Number of balls.	Endurance of the guns.
1	2	1	20	2	17	Gun No. 1 burst at the 13th fire.
2	2	2	21	2	17	
3	2	3	22	2½	12	
4	2	4	23	2½	13	No. 4 burst at the 32d fire.
5	2	5	24	2½	14	
6	2	6	25	2½	15	
7	2	7	26	2½	16	No. 2 burst at the 36th fire.
8	2	8	27	2½	16	
9	2	9	28	2½	16	
10	2	10	29	2½	16	No. 3 burst at the 38th fire.
11	2	11	30	2½	16	
12	2	12	31	2½	16	
13	2	13	32	3	14	Nos. 1 and 4 defective.
14	2	14	33	3	15	
15	2	15	34	3	16	
16	2	16	35	3	16	
17	2	17	36	3	16	
18	2	17	37	3	16	
19	2	17	38	3	16	

All of the guns burst in the part between the breech and the trunnions; the part in the front of the trunnions remaining entire and uninjured in all of them. The part broken is generally split lengthwise into three parts; and each part is broken transversely into two, and sometimes, into three pieces.

Another parcel of four 6 pdr. guns was cast February 15th. The iron was of the same kind as that before used. The furnace was charged with 11,000 pounds, one-half of which consisted of remelted iron, which had been continued four hours in fusion at the first melting; the other half consisted of fresh pigs from the smelting furnace. The order of casting was as follows:—

No. 5.	—	Cast, after the iron had been in fusion, $\frac{1}{2}$ hour.
No. 6.	“ “ “ “	1 $\frac{1}{2}$ hours.
No. 7.	“ “ “ “	3 “
No. 8.	“ “ “ “	3 $\frac{1}{4}$ “

This casting was regular and satisfactory in all respects. The iron was at a suitable temperature, and in a sufficiently liquid state when cast into the gun-moulds. The castings remained in the moulds, imbedded in the earth, three and a half days after casting.

The endurance of the guns already proved, indicates that a charge of 3 pounds of powder and 16 balls is suitable for the maximum proof charge. The scale of charges to be used in this parcel was therefore revised, and so arranged, that each charge, in succession, would be of greater force than that immediately preceding; and, that there would be no repetition of equal charges until after the maximum was reached, when the latter would be repeated to the end.

The following table of the order of firing and of the charges used, is constructed upon this principle. A column is added, in which is inserted the ratio of the force of each of the several charges, compared with the established service charge as the unit. These ratios have been computed in conformity with the rules laid down by Dr. Hutton, and which appear to be substantially confirmed by the French Artillerists, in the last edition of the *Aide Mémoire*.

The powder used in all the proof charges was of Dupont's manufacture, of the year 1837. Proof range, 270 yards.

Charges used in the Extreme Proof of four 6-pdr. Guns, Nos. 5, 6, 7, 8. March 8, 1844.

Order of fire.	CHARGES.		Ratio of the force of charges.	Successive additions of force.	Order of fire.	CHARGES.		Ratio of the force of charges.	Successive additions of force.
	Pounds of powder.	Number of balls.				Pounds of powder.	Number of balls.		
Service ch.	1½	1	1.000	.265	20	2½	16	5.657	.140
1	2	1	1.265	.524	21	3	14	5.797	.203
2	2	2	1.789	.402	22	3	15	6.000	.197
3	2	3	2.191	.339	23	3	16	6.197	"
4	2	4	2.530	.298	24	3	16	"	"
5	2	5	2.828	.270	25	3	16	"	"
6	2	6	3.098	.249	26	3	16	"	"
7	2	7	3.347	.231	27	3	16	"	"
8	2	8	3.578	.217	28	3	16	"	"
9	2	9	3.795	.205	29	3	16	"	"
10	2	10	4.000	.195	30	3	16	"	"
11	2	11	4.195	.187	31	3	16	"	"
12	2	12	4.382	.179	32	3	16	"	"
13	2	13	4.561	.172	33	3	16	"	"
14	2	14	4.733	.166	34	3	16	"	"
15	2	15	4.899	.161	35	3	16	"	Decrease
16	2	16	5.060	.039	36	3	16	6.197	.400
17	2½	13	5.099	.193	37	6	7	5.797	"
18	2½	14	5.292	.185	38	6	7	5.797	"
19	2½	15	5.477	.180					

Summary of Results.

Guns.	Iron in fusion. Hours.	No. of fires made.	Powder used. Pounds.	Number of balls discharged.	Endurance.
No. 5	½	31	75	367	Burst at 31st fire.
" 6	1½	34	84	415	" at 34th fire.
" 7	3	38	102	461	Remains unbroken.
" 8	3¾	25	57	271	Burst at 28th fire.

It will be seen, that all of these four guns reached the maximum charge of 3 lbs. of powder and 16 balls; that No. 5 burst at the ninth full charge, No. 6 at the twelfth, and No. 8 at the third; and that No. 7 endured 14 maximum charges, and also two other heavy charges of a different kind, and that it remains unbroken.

The gun, No. 7, having endured 36 fires of the regular series, being three of the maximum charges beyond all others, and its relative strength being thus sufficiently ascertained, it was then fired twice, with the charge of 6 pounds of powder and 7 balls; that being the maximum charge used in the extreme proof of similar guns at Fort Monroe.

The relative endurance of these four guns follows the order of the rela-

tive duration in fusion, of the iron composing each, up to and including the third gun, cast when the iron had been three hours in fusion.

The fourth gun, cast three-fourths of an hour after the third, proves to be the weakest of the whole number. Nothing has been observed in the operations of casting, boring, or proving this gun, up to the last fire, that would indicate any imperfection or defect, that could account for its possessing less strength than either of the others; and its bursting at an earlier period, can therefore be attributed to no other cause, than that of its iron having been continued in fusion for a longer period of time.

These results appear to establish satisfactorily the facts; that a prolonged exposure of liquid iron to an intense heat, does augment the cohesive power of the iron; and, that this power increases as the times of exposure, up to some (not well ascertained) limit; and, that if extended beyond that limit, the strength of the iron is thereby diminished.

All of these guns have endured a very high proof. The weakest of the four endured two of the maximum charges, and burst at the third. This, if the rules given by Dr. Hutton be not erroneous, exceeds the endurance of any similar guns, of which there is any record in our service.

For the purpose of comparison, a statement of the proof charges used at Fort Monroe, in 1841 and 1842, and of the endurance of the guns tried, is here given.

No. of fires.	CHARGES USED.		Ratio of the force of charges.
	Pounds of powder.	No. of balls.	
1 to 20	2	1	1.295
21 to 40	3	2	2.191
41 to 50	3	3	2.683
51 to 52	6	7	5.797

Of the six guns tried, three were cast at different furnaces in Sweden, one in England, one in Belgium, and one in the United States. Two of these burst with the charge of 3 pounds of powder and 2 balls; one at the 38th, and the other at the 39th fire of the series. Three of them burst with the charge of 3 pounds and 3 balls; two at the 47th, and one at the 49th fire. The other, one of the Swedish guns, endured once the charge of 6 pounds and 7 balls, and burst at the second, being the 52d fire of the

series. The force of the charge last mentioned, under which the Swedish gun failed at the second fire, is computed to be less than that endured by all of the four guns proved here; the weakest of which, endured that force a greater number of times than the Swedish gun.

It was ascertained that the bores were sensibly enlarged by the firing, and that the enlargement was greatest a little below the line where the cartridge and first ball meet, diminishing from that line in either direction.

Gun No. 7 was measured at different periods of the firing.

The enlargement at the 23d fire	was	.008 inch.
“ “ “ 28th “	“	.011 “
“ “ “ 33d “	“	.015 “
“ “ “ 38th “	“	.018 “

The gun No. 6, at the 33d fire, the last one previous to its bursting, had enlarged .025 inch.

The vents, also, were considerably enlarged. In gun No. 7, the diameter of the vent has increased from .18 to .32 inch at the exterior orifice.

Respectfully submitted,

W. WADE.

So. BOSTON FOUNDRY, *March* 16, 1844.

REPORT

ON THE

TRANSVERSE STRENGTH OF CAST IRON, OF DIFFERENT KINDS,

AND

OF THE SAME KINDS, DIFFERENTLY TREATED.

APRIL, 1844.

REPORT

ON THE
TRANSVERSE STRENGTH OF CAST-IRON OF DIFFERENT KINDS,
AND
OF THE SAME KINDS, DIFFERENTLY TREATED.

BY
JAMES B. HARRISON, ESQ.,

OF THE SAME KINDS, DIFFERENTLY TREATED.

APRIL, 1844.

The following report is the result of experiments made at the request of the Board of Ordnance and Fortification, and is intended to show the relative strength of different kinds of cast-iron, and of the same kind, differently treated. The experiments were made at the Arsenal, Woolwich, in the month of April, 1844, and the results were published in the month of May, 1844. The experiments were made by Mr. James B. Harrison, Esq., of the Arsenal, Woolwich, and the results were published in the month of May, 1844. The experiments were made by Mr. James B. Harrison, Esq., of the Arsenal, Woolwich, and the results were published in the month of May, 1844.

REPORT

OF

EXPERIMENTS MADE AT SOUTH BOSTON FOUNDRY, TO DETERMINE
THE TRANSVERSE STRENGTH OF DIFFERENT KINDS OF CAST IRON,
AND OF THE SAME KINDS, CAST UNDER DIFFERENT CIRCUM-
STANCES, OF TEMPERATURE, AND OF EXPOSURE IN FUSION.

THE annexed tables exhibit the details of the trials made, with the results reduced to a common unit.

The bars were cast two feet long, and generally, two inches square. When tried, they were supported, at both ends, on knife edges, which were 20 inches apart.

The columns headed "deflection" and "set," show the quantity of deflection and of permanent set, under a given pressure, which is designed to be near to, but somewhat less, than the minimum breaking weight.

The column headed "last deflection" gives the amount of deflection, under the pressure of the breaking weight. These measures are sufficiently accurate for the purpose of comparison, but they are not strictly correct; for the measure given includes the penetration of the knife edges, which support the bar at its ends. The true deflection and permanent set is less than the quantity stated in the tables, by the amount which the knife edges penetrate the bar; and this is more or less, as the material is soft or hard.

A trial was made with cylindrical bars, in lieu of square bars. These generally broke at a point distant from that pressed, and the results were so anomalous, that the use of them was soon abandoned. The formula by which the strength of the round bars is computed, appears to be not quite correct; for the unit of strength in the round bars is uniformly much higher, than in the square bars cast from the same kind of iron.

The experiments numbered 41 to 46, were designed to show the effects of casting the liquid iron at a high, or at a low temperature; and also, the effect of rapid, or of slow cooling in the mould. The results are not of a strikingly marked character. A high temperature at casting appears, however, to be beneficial, both for the strength and for soundness. Casting at a low temperature produces cavities in the bar. The beneficial effect of slow cooling is not so apparent.

Bars alloyed with zinc, numbered 54 and 55, were tried, but they proved unsuccessful.

The results of the numerous trials made to determine the effect of continuing the liquid iron in fusion, for longer or shorter periods of time before casting, are grouped together in classes, in a Recapitulation, at the end of the tables, which exhibits the mean results of each class. And although these results are not entirely free from anomalies, they show generally, a gradual and positive increase of strength, as the iron is continued in fusion for longer periods of time.

The iron prepared for casting the 10 inch gun, No. 61 (trials numbered 57 to 75), affords the best example of the effect; as, in this case, numerous bars were taken on four different days, from the same parcel of iron, in all its different stages of the second and third fusion, from the first melting of the pigs up to the casting of the gun. They were taken, also, at a late period of the experiments, when experience had suggested what precautions were necessary for insuring accurate results.

The following gives a brief view of these results:—

Second Fusion.

	Strength.	Ratio.
First casting, made as soon as the pig iron was melted	6506	1000
Second casting, iron in fusion one hour	7316	1124
Third casting, iron in fusion two hours	8256	1269
Fourth casting, in fusion three hours	8378	1287

Third Fusion.

Seventh casting, iron in second fusion $1\frac{1}{2}$ hours, whole time in fusion $4\frac{1}{2}$ hours	10411	1600
---	-------	------

From this it appears, that the cohesive power of the iron, so far as it can

be shown by its capacity to resist transverse strains, is increased by its continued exposure in fusion, from 100 to 160, or 60 per cent.

The transverse strength is that most generally measured, when determining the quality of different materials. It is believed, however, that a more accurate measure of the cohesive power of iron, designed for cannon, may be found in its *tensile* strength; that is, its power to resist being torn asunder by a force exerted in the direction of its length. The breaking instrument used in these experiments is not, at present, adapted for measuring this kind of resistance.

Respectfully submitted,

W. WADE.

April 2, 1844.

Experiments to ascertain the Transverse Strength of Cast Iron.

KIND OF IRON.	Hours in fusion.	No. of trial.	DIMENSIONS OF BAR.		DEFLECTION AND SET.			Last deflection.	Breaking weight. Pounds.	Unit of strength.	REMARKS.
			Breadth.	Depth.	Weight.	Deflection.	Set.				
Amenia Furnace; 2d fusion	1	1	2.028	2.049	10800	.122	.027	.160	12487	7333	
	2	2	1.982	2.047	10800	.155	.052	.177	11531	6942	
	3	3	1.995	2.043	10800	.099	.017	.192	15525	9322	
	0	4	2.003	2.040	10800	.116	.027	.165	13219	7929	
Richmond Iron; 2d fusion	1	5	2.000	2.031	10800	.139	.035	.156	11587	7022	
	2	6	2.003	2.036	10800	.118	.027	.152	12487	7519	
	1 ½	7	2.036	2.046	10800	.094	.017	.152	15019	8811	
	2	8	1.968	2.057	10800	.081	.008	.147	15525	9322	
Franklin Iron; 2d fusion	1 ½	9	2.025	2.058	10800	—	—	.205	12712	7410	
	2	10	2.000	2.054	10800	.137	.041	.200	12712	7533	
	2 ¾	11	1.994	2.008	10800	.117	.029	.198	13950	8675	
	1	12	1.989	2.013	10800	.130	.035	.260	11700	7258	
Franklin Iron; hematite ore; 2d fusion	1	13	2.010	2.053	10800	.121	.030	.162	13500	7967	
	1 ½	14	2.000	2.081	10800	.115	.026	.217	15244	8800	
	2 ½	15	2.019	2.055	10800	.110	.026	.196	15103	8857	
	½	16	2.007	2.038	10800	.123	.030	.205	13950	8367	
Stockbridge Iron; 2d fusion	1	17	2.017	2.027	10800	.140	.040	.162	11812	7126	
	1 ½	18	2.000	2.033	10800	.122	.029	.195	14512	8778	
	2	19	2.003	2.020	10800	.100	.015	.202	16481	10083	
	0	20	1.988	2.053	10800	.087	.012	.230	19462	11614	
Franklin Iron, for 6-pdr. guns, Nos. 1, 2, 3, and 4, cast from the same melting, at 3d fusion	0	21	2.025	1.980	9000	.145	.065	.250	12987	8179	Duplicate bars, cast with 6-pdr. gun No. 1.
	1	22	2.020	1.990	9000	.115	.030	.217	13365	8354	
	2	23	2.030	1.990	9000	.092	.018	.220	15363	9555	Cast with gun No. 2.
	3	24	2.030	1.990	9000	.080	.010	.195	14616	9091	
	1	25	2.020	2.050	9000	.075	.011	.152	13788	8121	Cast with gun No. 3.
	2	26	2.050	2.070	9000	.070	.010	.170	14850	8453	
	3	27	2.025	2.060	9000	.067	.010	.175	16056	9342	Cast with gun No. 4.
		28	2.035	2.020	9000	.062	.009	.170	16722	10069	

Franklin Iron, for 6-pdr. guns, Nos. 5, 6, 7, and 8; 3d fusion	$\frac{1}{2}$	29	1.978	2.003	10800	.121	.029	.155	12994	8187	Cast with gun No. 5.
	$1\frac{1}{2}$	30	1.930	2.003	10800	.116	.025	.217	15300	9880	" No. 6.
	3	31	1.977	2.028	10800	.102	.020	.200	15862	9754	" No. 7.
	$3\frac{3}{4}$	32	2.010	2.008	10800	.098	.017	.202	16172	9977	" No. 8.
ROUND BARS.											
Franklin Iron, for 4, 6-pdr. guns, Nos. 5, 6, 7, and 8; 2d fusion	$\frac{1}{2}$	33	—	Diameter.	7920	.133	.028	.237	10437	11766	Cast with gun No. 5.
	$1\frac{1}{2}$	34	—	1.960	7920	.142	.031	.166	8665	9620	" No. 6.
	3	35	—	2.000	7920	.132	.034	.254	11112	11790	" No. 7.
	$3\frac{3}{4}$	36	—	1.960	7920	.140	.031	.240	10606	11956	" No. 8.
	1	37	—	1.975	7920	.235	—	—	7920	8726	Cast at second fusion.
	2	38	—	1.950	7920	.169	.049	.240	9270	10612	
	3	39	—	1.953	7920	.170	.054	.262	9481	10804	
	4	40	—	1.975	7920	.172	—	—	7920	8726	
SQUARE BARS.											
Cast with gun 55, all from the same ladle; temperature, at the time of casting,	3	41	2.040	2.015	8415	.085	.017	.162	13545	8176	Cooled slowly in dry sand moulds.
	3	42	1.980	2.025	8415	.085	.015	.150	13122	8081	
	3	43	2.030	2.015	9000	.085	.015	.142	13770	8353	Cooled rapidly in green sand moulds.
	3	44	2.010	1.950	8415	.133	.047	.282	14868	9726	
Cast with gun 56,	3	45	1.940	2.030	8415	.085	.018	.155	13113	8201	Cast in dry sand mould.
	3	46	1.970	2.160	—	—	—	—	12852	6991	
	3	47	1.948	1.975	10800	.118	.024	.179	13950	9180	Bar unsound; with cavities.
	$3\frac{1}{2}$	48	2.125	2.053	10800	.047	.000	.067	14822	8274	
Cast with gun 57,	$3\frac{1}{2}$	49	2.140	2.071	10800	.056	.006	.067	13359	7277	Unsound; small cavities.
	$3\frac{1}{2}$	50	1.991	2.026	10800	.110	.020	.132	11869	7262	
Cast with gun 58,	$3\frac{1}{2}$	51	1.965	2.007	10800	.111	.020	.148	12881	8137	Exceedingly defective; flaws. Less zinc than in No. 54.
	3	52	2.125	2.075	10800	.057	.007	.057	10800	5902	
Cast with gun 59,	3	53	2.045	1.985	10800	.130	.021	.175	12431	7714	Cast in dry sand mould.
	3	54	—	—	—	—	—	—	—	—	
	3	55	2.015	2.022	10800	.115	.022	.115	10800	6555	
	3	56	2.003	1.970	10800	.104	.017	.135	12459	8014	

SQUARE BARS.

The bars were each 24 inches long, supported at both ends, the breaking force applied in the middle; distance between the supports 20 inches. The unit of strength represents the weight, in pounds, required to break a bar one inch square, supported at one end; the weight being applied at a distance of one inch from the point of support. For square bars, it is determined by this formula: $\frac{l w}{4 b d^2} = S = \text{the unit of strength.}$ l , being the length between the supports; w , the breaking weight; b , the breadth of the bar; and d , its depth.

For circular bars, $58905 d^3$ is substituted for $b d^2$; d being the diameter.

First fusion denotes the original pig, as made at the smelting furnace from the ore.

Second fusion denotes iron, which has been once melted in the foundry furnace.

Third fusion, such iron as has been twice melted at the foundry.

RECAPITULATION.

Comparative Strength of the same kinds of Iron, Cast at different Periods of Fusion.

KINDS OF IRON.	No. of trials.	1ST CASTING.		2D CASTING.		3D CASTING.		4TH CASTING.		REMARKS.
		Set.	Strength.	Set.	Strength.	Set.	Strength.	Set.	Strength.	
Amenia Furnace	1 to 4	.027	7333	.052	6942	.022	8625			
Richmond Furnace	5 to 8	.035	7022	.027	7519	.012	9066			
Franklin Furnace	9 to 12	—	7410	—	7533	—	7966			
Franklin; Hematite	13 to 16	.030	7967	.026	8800	.028	8612			
	Mean	.031	7433	.035	7698	.021	8567			
Stockbridge Furnace	17 to 20	.040	7126	.029	8778	.015	10083			} 3d fusion.
Franklin } Nos. 1, 2, 3, 4	21 to 28	.065	8179	.018	9555	.011	8121	.012	11614	
Iron, } Nos. 5, 6, 7, 8	29 to 32	.030	8354	.010	9091	.010	8453	.010	9342	
8, 6-pdr. guns		.029	8187	.025	9880	.020	9754	.017	10069	
	Mean	.041	8240	.018	9509	.014	8776	.012	9796	
	57 to 60		6207	.042	7384	.039	8303	.038	8052	} 2d fusion.
	61 to 64		6657	.052	7528	.033	8295	.019	8973	
	65 to 68		6653	.055	7035	.036	8171	.042	8108	
	Mean		6506	.050	7316	.036	8256	.033	8378	
Franklin Iron, for 10-in. guns	73					.024	11046			} 3d fusion; 1st and 2d castings im-perfect.
	74					.016	9777			
	Mean					.020	10411			

REPORTS

REPORTS

ON THE

STRENGTH OF IRON AND ON THE DURABILITY OF HEAVY CANNON.

OCTOBER, 1844.

REPORTS

STRENGTH OF IRON AND ON THE DURABILITY OF BRASS

REPORTS

WASHINGTON, D.C. 1881

For the purpose of determining the strength and durability of iron and brass, a series of experiments were conducted on the subject of the strength of iron and brass under various conditions of stress and strain.

The first series of experiments was conducted on the subject of the strength of iron under various conditions of stress and strain.

The second series of experiments was conducted on the subject of the strength of brass under various conditions of stress and strain.

The third series of experiments was conducted on the subject of the strength of iron under various conditions of stress and strain.

The fourth series of experiments was conducted on the subject of the strength of brass under various conditions of stress and strain.

The fifth series of experiments was conducted on the subject of the strength of iron under various conditions of stress and strain.

REPORTS

ON THE

STRENGTH OF IRON AND ON THE DURABILITY OF HEAVY CANNON.

WASHINGTON, *October 12, 1844.*

COLONEL G. BOMFORD:

SIR: I now submit reports on the strength and density of cast iron, and on the proof of trial guns, viz:—

A report on the strength and density of cast iron; being a continuation and conclusion of those heretofore presented upon the same subject:

A report of the experiments made to ascertain the durability of the new model heavy 8 and 10-inch howitzers, under continuous firing with service charges:

A report of the experiments made in the extreme proof of cannon under a hydrostatic pressure:

And a report of an examination of the iron used in the construction of the wrought-iron cannon, which burst on board the Steamship Princeton, February 28, 1844. This consists, chiefly, of a report made to the Franklin Institute, Philadelphia; with an additional statement, since prepared, showing the tenacity and density of all the several kinds of wrought iron tried.

These experiments have supplied much information of a practically useful character. The breaking machine, which determines the tenacity of iron, in either of the forms of tension or of transverse breaking, furnishes a convenient and accurate method of testing the quality of iron, before it is used in casting cannon. It, therefore, enables the founder to select his materials for cannon, with greater certainty and safety. It enables him, also, to determine the comparative utility of the different methods of melt-

ing and casting the iron. It will be seen by the results detailed in the reports on this subject, that the quality of the iron is essentially changed, by the different methods of treating it while in the melted state, and by different methods of cooling it after it is cast into the moulds. It is found, that the same iron is greatly improved in quality, by retaining it in the furnace after it is melted for considerable periods of time; and that it is further improved, by casting it into pigs and again remelting it.

But it is known, also, that a continuation of this process will ultimately impair the tenacity of the iron, and render it wholly unfit for use. It is found, also, that different kinds of iron require a different treatment in order to produce the best effect. The breaking instrument enables one to ascertain the effect produced by these processes, in all their several stages of progress; and to decide on that which is found most suitable for making guns of the best quality.

The experiments, thus far, have developed new facts, and contributed materially to improve the art of manufacturing cannon; and they should be continued and extended with a view to further improvements, whenever suitable opportunities may occur. The trials made in the course of these experiments have suggested methods, by which, it is conceived, the quality of cannon made in former times may be ascertained with some degree of precision, without resorting to those excessive proofs, which, while they serve to detect bad guns, impair or destroy those which are good. As there are many such ancient guns now on hand, the quality of which it is desirable to ascertain, I suggest the following course of proceedings, as best adapted to the purpose.

First, cut from the centre of one of the trunnions,* a cylinder not less than one inch diameter, and two inches long. A cylinder of larger diameter would be preferable, and should be taken, when circumstances permit. The operation of cutting, will denote the degree of hardness of the metal; and this is one of the particulars to be carefully observed and recorded. The appearance of the fracture at the end of the cylinder, made by detaching it from the trunnion, should also be noted. The cylinder

* In the experiments since made, it was found, that samples cut from the trunnions, were not reliable for giving a true measure of the quality of the metal in the body of the gun. The samples were afterwards taken from the face of the muzzle.

should then be dressed in the turning lathe to a suitable form for testing in the breaking machine; but before breaking it, its specific gravity should be ascertained by the use of distilled water. After this, the specimen is to be pulled asunder in the breaking instrument. By these methods, all the principal physical qualities of the iron will be ascertained; and although these may be insufficient for determining, with absolute certainty, the quality of the guns, they will do much to assist in forming a correct judgment upon them, and will serve, at least, to detect such as are of a decidedly bad quality.

The use of the hydrostatic instrument will detect any cracks or flaws which may exist in the guns, if any such were formed in the casting or the cooling, or were produced by the excessive proof-charges, to which some of them have been subjected. It will serve, also, to determine the compactness, or the porosity of the iron, and may be otherwise useful as an auxiliary to other tests. The hydrostatic pressure should not be so much extended as to produce fracture, or an injurious strain upon the gun. Judging from the few experiments of this character already made, the pressure may be safely extended to four thousand pounds per inch, without injury to the gun, if, the least thickness of the metal, in the part strained, is equal to half a calibre. If any gun will permit the water to pass through the iron freely, under a pressure of this kind, it may well be considered of doubtful character; although it remains yet to be determined, what degree of porosity should cause the condemnation of a gun.

After several guns of the same calibre shall have been tested in the manner stated, and the results compared, some few of them should be selected for an extreme proof by firing. In selecting the guns for this purpose, regard should be had to the indications of quality exhibited in the previous tests; selecting first, one which appears to possess the least strength, and then another of the greatest strength. It may also be proper to select another of intermediate quality. But the number and kinds to be selected, can be better determined, after ascertaining by the other tests mentioned, what diversity of character exists among them, and by what peculiarity, any of them may be marked.

The series of proof-charges most suitable for determining the endurance of guns, in proofs of this kind, is that which commences with the ordinary service-charge, and gradually increases in force, at each successive fire; the

maximum, to consist of a cartridge equal to half the weight of the ball, and as many balls as the bore will contain. The cartridges to be $\frac{3}{12}$, $\frac{4}{12}$, $\frac{5}{12}$, and $\frac{6}{12}$, the weight of the ball. Beginning with $\frac{3}{12}$ and 1 ball, an additional ball to be added at each fire up to the tenth; then with a cartridge of $\frac{4}{12}$, begin with the least number of balls which will produce a force greater than that of the last preceding fire, and add one ball at each successive fire, up to 10 balls. Then proceed, in like manner, with the cartridges of $\frac{5}{12}$ and of $\frac{6}{12}$, and with the latter cartridge, continue to augment the number of balls until the bore is filled, and then repeat this last charge, until the gun bursts. The balls to be fired into a butt of sand, in order that they may be recovered and re-fired.

After a gun has been broken by firing, a proof bar, 33 inches long and $2\frac{1}{2}$ inches square, should be cut from a sound part of it, and be subjected to trial in the breaking machine, to determine both its transverse and tensile strength; and then its specific gravity should be ascertained. All the results obtained from this proof bar should be noted, in like manner with those obtained from the trunnion specimen, and be compared with them.

As the proof by firing, to be satisfactory, will necessarily destroy the gun, or leave it unfit for future service at least, no greater number should be proved in this manner, than may be found necessary to verify the accuracy, or to measure the value of the previous tests, which are applied without overstraining or injuring the gun.

Respectfully, your ob't serv't,

W. WADE.

REPORT

OF

EXPERIMENTS ON THE STRENGTH OF CAST IRON,

MADE AT BOSTON,

SEPTEMBER, 1844.

REPORT

REPORT MADE AT THE REQUEST OF THE BOARD OF DIRECTORS OF THE
THE UNIVERSITY OF CALIFORNIA

REPORT

The following report was prepared by the Board of Directors of the University of California, and is submitted to the Board of Regents for their consideration. The report is divided into two parts, the first of which deals with the general condition of the University, and the second with the financial condition. The first part is divided into three sections, the first of which deals with the general condition of the University, the second with the condition of the various departments, and the third with the condition of the various faculties. The second part is divided into two sections, the first of which deals with the financial condition of the University, and the second with the financial condition of the various departments. The report is based on the information furnished to the Board of Directors by the various departments and faculties, and is intended to give a general view of the condition of the University at the end of the year.

The first part of the report deals with the general condition of the University. It is divided into three sections, the first of which deals with the general condition of the University, the second with the condition of the various departments, and the third with the condition of the various faculties. The second part of the report deals with the financial condition of the University. It is divided into two sections, the first of which deals with the financial condition of the University, and the second with the financial condition of the various departments. The report is based on the information furnished to the Board of Directors by the various departments and faculties, and is intended to give a general view of the condition of the University at the end of the year.

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W. WADE

Director, University of California

R E P O R T

OF

EXPERIMENTS MADE AT SOUTH BOSTON FOUNDRY, TO DETERMINE
THE STRENGTH OF DIFFERENT KINDS OF CAST IRON.

THE following table, No. 1, including specimens numbered from 86 to 142, is a continuation of former reports of the transverse strength of proof bars.

Table No. 2 gives the transverse and the tensile strength, and the specific gravity, of sundry specimens. These two statements, with those presented in April last, give the results, in detail, of all the specimens tried.

No. 3 exhibits the strength and density of the proof bars, which were cast, at the same time with the cannon made at Boston, during the year past.

No. 4 is a statement of the comparative transverse strength of proof bars, cast at different periods of fusion. An inspection of the mean results exhibited in this statement will show, that the same iron is greatly increased in strength, by its being continued in fusion, and by its being remelted.

No. 5 is a statement, in a condensed form, of the comparative strength and density of iron cast, at different periods of fusion. It exhibits an uniform improvement of the quality of the iron, in all respects, by continuance in fusion, and remelting, and, it shows how much its quality depends on its treatment in the furnace.

No. 6 compares the strength and density of iron, as it exists in the body of the gun, with the strength and density, as it is found in the proof bars, cast from the same iron, at the same time, in different moulds. By this it will be seen, that the tensile strength is greatest in the gun, and that the transverse strength is greatest in the separate bar.

No. 7 shows the different results of density, when obtained from rough fragments, and from dressed specimens; the latter, uniformly giving the highest density.

Respectfully submitted,

W. WADE.

Boston, *September 1, 1844.*

SAMPLES.	Time in fusion.	DIMENSIONS OF BAR.			DEFLECTION AND SET.			Breaking weight. Pounds.	Strength. Value of S.	REMARKS.
		Breadth.		Depth.	Weight. Pounds.	Deflection.	Set.			
		Inches.	Inches.	Inches.						
8-inch gun No. 62	1	2.022	2.003	.105	.023	.180	14571	8981	Third fusion; cast before the gun.	
10-inch gun No. 63	1½	2.021	2.001	.140	.015	.145	15354	9487	Third fusion; cast with the gun.	
8-inch gun No. 64	1	2.003	2.026	.085	.013	.205	17352	10553	Cast before the gun } 3d fusion; burst	
10-inch gun No. 65	1½	1.972	2.016	.087	.016	.185	16312	10176	Cast with the gun } in extreme proof.	
	1½	1.994	2.011	.080	.010	.120	14737	9138	Cast from large furnace } 3d fusion.	
	1½	1.998	2.056	.073	.009	.100	13896	8222	Cast from small furnace }	
8-inch gun No. 66	1	2.000	2.024	.089	.016	.155	15581	9509	Cast before the gun,	
	1½	1.971	2.035	.088	.016	.185	17496	10717	Cast with the gun in se- } 3d fusion.	
									parate mould,	
10-inch gun No. 67	1½	2.010	1.986	.130	.024	.145	13556	8550	Cast in the gun mould,	
	1½	2.014	1.994	.085	.015	.165	16481	10291	Cast with the gun in separate mould,	
									3d fusion; extreme proof.	
	0	2.000	2.002	.116	—	.200	9900	6175	5571 mean.	
	0	2.012	1.999	.170	—	.185	7987	4967		
	0	2.009	2.010	—	—	.130	9900	6099	6862 mean.	
	0	2.019	2.063	.116	.023	.157	13106	7626		
	1	2.014	2.092	.099	.022	.142	13894	7882		
	1	1.975	2.048	.100	.017	.141	13275	8013	7947 mean.	
	1½	2.019	2.069	.102	.025	.134	13106	7582		
	1½	2.032	2.059	.095	.020	.144	14231	8260	7921 mean.	
	2	2.018	2.086	.080	.017	.133	16369	9321		
	2	2.013	2.055	.081	.014	.171	18394	10819	10070 mean.	
	2½	2.003	2.070	.090	.020	.170	18844	10978		
	2½	1.983	2.152	.072	.012	.122	17044	9280	10129 mean.	
	3	2.004	2.073	.092	.020	.178	18337	10646		
	3	1.999	2.076	.089	.016	.197	18900	10969	10807 mean.	
	0	1.993	1.960	.124	.030	.180	13221	8634		
	0	2.027	2.046	.115	.030	.155	13383	7886		
	0	2.098	1.985	.107	.025	.160	13387	8097		
	0	2.007	1.994	.132	.030	.230	15075	9446		
	0	2.021	1.984	.140	.044	.140	11196	7037	8182 mean; 1st fusion.	
	0	2.002	1.965	.143	.045	.165	11646	7533		
	0	1.994	1.965	.182	.032	.190	13446	8732		
	0	2.076	2.002	.104	.023	.140	13475	8097		

6-pdr. guns, broken in the extreme proof	No. 6	1½	118	2.015	2.020	10800	.117	.027	.217	13837	8415	The bar cut from the chase of the broken gun.	
	No. 8	3¾	119	1.697	2.023	9900	.114	.025	.210	12825	9233	The bar cut from the chase of the broken gun.	
	No. 9		120	2.006	2.001	10800	.155	.090	.250	12769	7949	The bar cut from the chase of the broken gun; this bar bent and set similar to wrought iron.	
9-pdr. trial gun		{ 2 } { 1½ }	121	2.000	1.992	10800	.099	.020	.195	14850	9356	Cut from the chase of the broken gun; cast at 3d fusion.	
8-inch gun No. 50	{ Lower end Upper end	3½	122	1.879	1.884	7200	.087	.006	.150	9675	7253	} Mixed, 2d fusion ¼, 3d fusion ½; Bars cut from the runners in.	
			123	1.887	1.840	7200	.093	.020	.152	9337	7307		
8-inch gun No. 51; Lower end		3	124	1.893	1.895	7200	.084	.015	.130	9562	7033		
8-inch gun No. 54;	{ Lower end Upper end	3½	125	1.859	1.850	7200	.083	.011	.152	10462	8222	} Mixed, 2d fusion ½, 3d fusion ¾;	
			126	1.868	1.850	7200	.078	.010	.157	10800	8446		
8-inch gun No. 64	{ Lower end Upper end	1½	127	2.003	2.017	10800	.117	.035	.207	13612	8352	{ All 3d fusion; 2 specimens from the same bar, cut from the body of the gun burst at the 729th fire.	
			128	2.018	2.010	10800	.115	.035	.228	14346	8798		
			129	2.010	2.010	10800	.135	.035	.155	11587	7135	Bar cut from the chase of the gun.	
Old 18- pdr. guns { Burst in Aug. 1844 Burst by firing in Sept. 1844		½	130	—	—	10800	.135	.035	.162	12037	7386	Bar cut from the chase of the gun.	
			131	1.991	1.995	7200	.110	.020	.165	8212	5302	{ Iron prepared for remelting; to be used in casting Navy Guns, at 3d fusion.	
			132	1.993	1.993	7200	.097	.021	.175	9900	6253		
Same melting, 2d fusion; Franklin iron	{ 1 2 2½		133	2.007	2.005	7200	.087	.018	.137	9337	5786		
			134	1.973	1.997	7200	.097	.025	.200	10746	6829	{ Bar defective } Dark } Long Mine ore.	
			135	1.993	1.987	7200	—	—	.110	—	—		
Stirling pig iron from the ore, Southfield Furnace, New York, W. H. Townsend, 1st fusion			136	1.983	1.995	7200	.071	.013	.095	8778	5559	{ Bar defective } gray } Long Mine ore.	
			137	1.984	1.979	7200	.060	.010	.152	13275	8542		
			138	1.983	1.975	7200	.055	—	.090	10233	6615		
			139	1.983	1.972	7200	.070	.010	.135	11025	7006	{ Bar defective } gray } Long Mine and Causeway ores mixed.	
			140	1.988	1.987	7200	.065	—	.125	10683	6805		
			141	1.983	1.991	7200	.067	—	.125	10233	6509		
			142	1.996	1.990	7200	.050	—	.130	13725	8682	Long Mine and Causeway ores mixed; bar defective, a small cavity.	

September 17, 1844.

No. 2.—Statement of the Transverse and Tensile Strength, and of the Specific Gravity of Cast Iron.

DESCRIPTION OF IRON.	Time in fusion.	STRENGTH PER SQUARE INCH.		Specific gravity.	REMARKS.
		Transverse.	Tensile.		
Specimen taken from the trunnion of an old 24-pdr. gun	—	—	—	7.196	
From the chase of an old 18-pdr. gun, burst by hydrostatic pressure	—	7590	27359	7.312	
	$\frac{1}{2}$	7126	17843	7.187	
	1	8778	20127	7.217	
	$1\frac{1}{2}$	10083	24387	7.250	
	2	11614	34496	7.279	
	$\frac{1}{2}$	8187	25969	7.225	
	$1\frac{1}{2}$	9880	29143	7.263	
	3	9754	27755	7.274	
	$3\frac{3}{4}$	9977	30039	7.248	
	$\frac{1}{2}$	—	—	7.203	
	$1\frac{1}{2}$	—	—	7.235	
	3	—	—	7.274	
	$3\frac{3}{4}$	—	—	7.298	
	$1\frac{1}{2}$	8415	30234	7.196	
	$3\frac{3}{4}$	9233	29760	7.278	
	$3\frac{3}{4}$	—	32414	—	
	—	7949	26764	7.217	
	$3\frac{1}{2}$	9356	33307	7.287	
	—	—	—	7.237	
	—	—	—	7.275	
	—	6146	19429	7.108	
	3	9180	25376	7.291	
	$3\frac{1}{2}$	8137	27357	7.290	
	3	8014	28453	7.297	
	$2\frac{3}{4}$	9230	28453	7.336	
	$2\frac{3}{4}$	8397	23592	7.324	

Specimen taken from the trunnion of an old 24-pdr. gun

From the chase of an old 18-pdr. gun, burst by hydrostatic pressure

Stockbridge Furnace

Proof bars, cast separately at the time of casting the gun

6-pdr. trial guns; proved in March 1844

Specimens taken from the trunnions of the guns

Bars cut from the chase of the guns after bursting

From the chase of the 9-pdr. trial gun proved in April, 1842

From a fragment of a Finspong 12-pdr. gun burst at Fort Monroe

From a trunnion of a 6-pdr. alloyed with copper

Franklin Furnace proof bar, planed from the original pig

8-inch howitzer No. 56

10-inch howitzer No. 57

8-inch howitzer No. 59

8-inch howitzer No. 60

10-inch howitzer No. 61	2d fusion from the pigs	0	6657	15861	7.196
		1	7528	20420	7.234
		2	8295	24383	7.270
		3	8973	25773	7.283
	3d fusion from remelted pigs	1 1/2	11046	32022	7.353
		1 1/2	9777	27359	7.351
		1	8981	—	7.163
8-inch howitzer No. 62; 3d fusion; Cast before the gun		1 1/2	9487	31027	7.321
10-inch howitzer No. 63; 3d fusion; Cast with the gun		1	10553	26764	7.303
8-inch howitzer No. 64; 3d fusion; { Cast before the gun		1 1/2	10176	24583	7.331
10-inch howitzer No. 65; 3d fusion; { Cast with the gun		1 1/2	9138	24980	7.402
	{ Cast before the gun	1	9509	26169	7.339
8-inch howitzer No. 66; 3d fusion; { Cast in separate mould		1 1/2	10717	28453	7.357
	{ Cast in gun mould	1 1/2	8550	23989	7.330
10-inch howitzer No. 67; 3d fusion; Cast in separate mould		1 1/2	10291	22402	7.379
8-inch gun No. 50 { Lower end of runner in gun mould		3 1/2	{ 7253	—	7.227
8-inch gun No. 51; { Upper end of runner in gun mould		3	{ 7307	15226	7.235
8-inch gun No. 54 { Lower end of runner in mould		3 1/2	{ 7033	21411	7.248
From the chase of 8 inch gun No. 64, burst in proof by		1 1/2	{ 8222	25971	7.275
firing at the 729th service charge		—	{ 8446	24742	7.281
From the chase of 18- pdr. guns, burst	{ By water proof, August 19, 1844	—	{ 8352	25773	7.276
	{ By firing, September 5, 1844	—	{ 8798	26962	7.328
	{ 6-pdr. trial gun No. 5	—	7135	22204	7.384
	{ 6-pdr. trial gun No. 6	1 1/2	7386	16849	7.078
	{ 6-pdr. trial gun No. 8	3 1/2	—	—	7.108
Rough, undressed fragments, from bursted guns	{ Finspong 12-pdr., burst at Fort Monroe	—	—	—	7.200
	{ Old 10-inch gun, burst at Boston, 1841	—	—	—	7.126
		—	—	—	6.926

{ Two specimens from one bar.
Too hard for the file.
Too hard for the file.
Specimens taken from the vicinity of the trunnions.

W. WADE.

SOUTH BOSTON FOUNDRY, September 17, 1844.

No. 3.—*Transverse and Tensile Strength, and Specific Gravity of Proof Bars, cast at the same time with Cannon, in separate Vertical Dry-sand Moulds.*

KINDS OF IRON.	Trans-verse strength.	Tensile strength.	Specific gravity.	REMARKS.		
8-inch gun No. 56	9180	25376	7.291			
10-inch gun No. 57	8137	27357	7.290			
8-inch gun No. 59	8014	28453	7.297			
8-inch gun No. 60	8814	26022	7.330			
10-inch gun No. 61	10411	29690	7.352			
8-inch gun No. 62	8981	—	7.163	Defective bar.		
10-inch gun No. 63	9487	31027	7.321			
8-inch gun No. 64	10176	24583	7.331	Extreme proof with service charges; burst at 729th fire.		
10-inch gun No. 65	9138	24980	7.402	Mottled.		
8-inch gun No. 66	10717	28453	7.357			
10-inch gun No. 67	10291	22402	7.379	Hard. Proof with service charges; endured 600 fires, unbroken.		
<i>Order of Endurance.</i>						
6-pdr. trial guns	No. 5	8187	25969	7.225	3d—burst at 31st fire	} Extreme charges, 3 pounds of powder and 16 balls; which filled the gun.
	No. 6	9880	29143	7.263	2d—burst at 34th fire	
	No. 7	9754	27755	7.274	1st— { Endured 38 fires; remained unbroken	
	No. 8	9977	30039	7.248	4th—burst at 25th fire	
Mean	9409	27232	7.302			
Least	8014	22402	7.163			
Greatest	10717	31027	7.402			

This table exhibits the measure of strength and density, of the proof bars cast with the guns made at the South Boston Foundry, during the year past, and shows the general quality of the iron used in the manufacture of these guns.

W. WADE.

SOUTH BOSTON FOUNDRY, *September 17, 1844.*

No. 4.—Comparative Transverse Strength of the same Kinds of Iron, cast at different Periods of Fusion.

KINDS OF IRON.	No. of trials.	1ST CASTING.		2D CASTING.		3D CASTING.		4TH CASTING.		REMARKS.
		Set.	Strength.	Set.	Strength.	Set.	Strength.	Set.	Strength.	
Amenia Furnace Richmond Furnace Franklin Furnace Same; hematite ore	1 to 4	.027	7333	.052	6942	.022	8625	—	—	Each 3d casting is a mean of 2 bars
	5 to 8	.035	7022	.027	7519	.012	9066	—	—	
	9 to 12	—	7410	.041	7533	.032	7966	—	—	
	13 to 16	.030	7967	.026	8800	.028	8612	—	—	
	Mean	.031	7433	.036	7698	.023	8567	—	—	Second fusion.
Stockbridge Furnace Amenia Furnace Franklin Furnace	17 to 20	.040	7126	.029	8775	.015	10083	.012	11614	Each casting is a mean of 2 bars
	98 to 109	.023	6862	.020	7947	.016	10070	.018	10807	
	131 to 134	.020	5302	.021	6253	.018	5786	.025	6829	
	Mean	.028	6430	.023	7659	.016	8646	.018	9750	
Franklin Iron, 6-pdr. guns, Nos. 1, 2, 3, 4, 5, 6, 7, and 8	21 to 28	.065	8179	.018	9555	.011	8121	.010	9342	Third fusion.
	29 to 32	.030	8354	.010	9091	.010	8453	.009	10069	
		.029	8187	.025	9880	.020	9754	.017	9977	
	Mean	.041	8240	.018	9509	.014	8776	.012	9796	
Franklin Iron for 10-inch gun No. 61	57 to 60	—	6207	.042	7384	.039	8303	.038	8052	Second fusion.
	61 to 64	—	6657	.052	7528	.033	8295	.019	8973	
	65 to 68	—	6653	.055	7035	.036	8171	.042	8108	
	Mean	—	6506	.050	7316	.036	8256	.033	8378	
	73	—	—	—	—	.024	11046	—	—	Second fusion; 1st and 2d castings imperfect.
	74	—	—	—	—	.016	9777	—	—	
	Mean	—	—	—	—	.020	10411	—	—	

W. WADE.

September 17, 1844.

No. 5.—*Transverse and Tensile Strength and Specific Gravity of Proof Bars, cast from the same Melting of Iron at different Periods of Fusion.*

	Period of fusion.	Stockbridge Iron, 2d fusion.	FRANKLIN IRON.		Mean.	Proportion.
			6-pdr. guns, 3d fusion.	Gun No. 61, 2d and 3d fusions.		
Transverse strength	1st	7126	8187	6657	7327	1.000
	2d	8778	9880	7528	8729	1.191
	3d	10083	9754	8295	9377	1.279
	4th	11614	9977	8973	10188	1.391
	7th	—	—	10411	—	—
Tensile strength	1st	17843	25969	15861	19891	1.000
	2d	20127	29143	20420	23230	1.168
	3d	24387	27755	24383	25508	1.282
	4th	34496	30039	25773	30103	1.513
	7th	—	—	29690	—	—
Specific gravity	1st	7.187	7.225	7.196	7.203	1.000
	2d	7.217	7.263	7.234	7.238	1.005
	3d	7.250	7.274	7.270	7.265	1.008
	4th	7.297	7.248	7.283	7.270	1.009
	7th	—	—	7.352	—	—

The iron used in the 6-pounder guns consisted in part of remelted pigs. The results stated under this head show the changes which occurred in the third fusion only; the changes produced by the second fusion of this iron were not ascertained.

W. WADE.

SOUTH BOSTON FOUNDRY, *September 17, 1844.*

No. 6.—*Comparison of Proof Bars cut from the body of the Gun, with those cast at the same time in Vertical Dry Sand Moulds; showing the difference in the same iron, caused by slow cooling in large masses and more rapid cooling in small castings.*

GUNS.	TRANSVERSE STRENGTH.		TENSILE STRENGTH.		SPECIFIC GRAVITY.	
	Bar cut from gun.	Bar cast separate.	Bar cut from gun.	Bar cast separate.	Bar cut from gun.	Bar cast separate.
6-pdr. gun No. 6	8415	9880	30234	29143	7.196	7.263
6-pdr. gun No. 8	9233	9977	31087	30039	7.278	7.248
8-inch gun No. 64	8575	10176	26367	24583	7.276	7.331
Mean	8741	10011	29229	27922	7.250	7.281
Proportional	1.000	1.145	1.000	.955	1.000	1.004

These results show that, in every instance, the transverse strength is augmented by rapid cooling in small castings, and that the tensile strength is increased by slow cooling in large masses. The differences in specific gravity are less marked; but it is somewhat higher in the small castings cooled rapidly.

W. WADE.

SOUTH BOSTON FOUNDRY, September 17, 1844.

No. 7.—*Comparison of Specific Gravities obtained from Rough Broken Fragments of Iron, and from Specimens, of the same Iron, dressed in a Planing Machine or Turning Lathe.*

KINDS OF IRON.	Rough fragments.	Dressed specimens.	Difference.
From trunnions of 6-pdr. No. 5 . . .	7.078	7.203	.125
“ “ No. 6 . . .	7.108	7.235	.127
“ “ No. 8 . . .	7.200	7.298	.098
From a Finspong 12-pdr. gun . . .	7.126	7.237	.111
Mean . . .	7.128	7.243	.115

The dressed specimens were carefully cut with a sharp tool, without compressing or disturbing the part designed for trial, in such manner that the specimen would represent truly the density of the mass from which it was taken. The results show, in every instance, that the rough fragments fell short of the dressed specimens; and, regarding the latter as giving the true density, it follows, that results obtained from rough fragments are not to be relied upon as accurate.

W. WADE.

SOUTH BOSTON FOUNDRY, *September 17, 1844.*

REPORT

ON THE

QUALITY OF WROUGHT IRON, IN THE GUN WHICH BURST

ON THE

U. S. STEAM SHIP PRINCETON,

FEBRUARY 24, 1844.

REPORT

ON THE QUALITY OF WROUGHT IRON IN THE CITY OF NEW YORK

IN THE CITY OF NEW YORK, IN THE YEAR 1871

THEY ARE THE PROPERTY OF THE CITY OF NEW YORK

Weight in pounds	Length in feet	Thickness in inches
10000	10	1.00
10000	10	1.00
10000	10	1.00
10000	10	1.00
10000	10	1.00
10000	10	1.00
10000	10	1.00
10000	10	1.00
10000	10	1.00
10000	10	1.00

The dimensions of the bar bodies and their bearing were as follows:

REPORT

OF THE

EXAMINATION OF THE IRON USED IN THE CONSTRUCTION OF THE
WROUGHT IRON CANNON WHICH BURST ON BOARD OF THE
STEAMSHIP PRINCETON, FEBRUARY 28, 1844.

Two bars of iron taken from the same parcel, and supposed to be of the same quality as that used in the construction of the gun, were furnished by Mr. Ward, the manufacturer. Another bar was cut from the body of the gun itself, as a representative of the quality of the iron as it existed in the gun at the time of its bursting. With these three bars, the following trials were made:—

The bar cut from the body of the gun, was reduced in a planing machine to two inches square, and was subjected to a transverse strain; supported at both ends on knife edges, twenty inches apart, and the weight applied in the middle. The different weights applied, with the deflections and the permanent set caused thereby, were as follows:—

Weights applied.	Deflection.	Permanent set.
10800 pounds.	.35 inches.	.30 inches.
12825 “	.61 “	.55 “
13950 “	.94 “	.87 “
15570 “	1.22 “	1.15 “
16650 “	1.52 “	1.44 “
17300 “	1.83 “	1.75 “

The dimensions of the bar before and after bending were as follows:—

Before bending; depth	1.988
“ breadth	1.993
After bending, measured in the middle where the weight was applied; depth	1.975
Breadth on the convex side	1.903
“ on the concave side	2.083
Difference of the two sides	.180

The bar endured this strain without exhibiting any cracks, or other indications of approaching rupture. One of the original bars, having the same dimensions, was tried in like manner, and gave similar results.

By these trials, it appears that, as far as the quality of stiffness is concerned, the iron has undergone no perceptible change in the process of forging the gun. Numerous trials have recently been made, in like manner, with bars of Cast Iron of the same dimensions, and it is found that the weights sustained by cast iron of good quality, such as is used in casting cannon, range from 14000 to 17000 pounds. On comparing these results, it appears that the weight required to break a bar of cast iron, by transverse strain, will bend a bar of wrought iron of like dimensions, and give it a permanent set varying from 1 to $1\frac{1}{4}$ inches; and, also, that a considerable permanent set is imparted to the wrought iron bar, by weights much less than the minimum breaking weight for cast iron.

To determine the tensile strength of the iron, or its power to resist being torn asunder by a force applied in the direction of the length of a bar, three specimens were taken from each of the bars mentioned. Two of the specimens taken from each bar, were reduced to a suitable form for breaking by tension, in a turning lathe, in order to leave the material in the same state as it existed in the bars, undisturbed by any heating or hammering. The third specimen from each bar, was drawn down under a welding heat, at a common smith's forge. All of them were reduced, in that part where the fracture would occur, to a uniform diameter of $\frac{6}{10}$ inch. The following results were obtained:—

From the original bars, representing the quality of iron before being welded in the fagot for the gun:—

Pounds per square in.

Two specimens from bar A { 45359 } Mean . . 45359
 { 45359 }
Two specimens from bar B { 50930 } Mean . . 48542
 { 46155 }

From the same bars, drawn under a welding heat:—

1 specimen from bar A 39375
1 specimen from bar B 49338
Mean of 6 specimens from original bars . . . 46086

From the bar cut from the body of the gun:—

Two specimens from the same bar, un- { 40585 } Mean 38595
 { 36606 } altered by heating or hammering
One specimen from the same bar, drawn under a weld-
ing heat 52521

It was observed that the bars began to yield, by extending in length and contracting in diameter, under a force much less than the maximum breaking weights. In trying the specimens cut from the body of the gun, the several reductions of diameter, under successive additions of weight, were accurately measured, and the results were as below.

Two Specimens in the Original State as cut from the Gun, and one Specimen from same Bar drawn down.

ORIGINAL STATE AS CUT FROM THE GUN.				SAME DRAWN DOWN.	
Weight per sq. in.	Diameter.	Weight per sq. in.	Diameter.	Weight per sq. in.	Diameter.
25458	.595	23100	.595	35320	.595
28640	.590	25458	.590	41390	.590
31822	.586	28640	.583	44570	.585
35204	.582	31822	.580	47760	.580
38187	.575	35204	.568	50940	.575
40585	.560	36606	.544	52521	.550
Fracture	.540	Fracture	.520	Fracture	.450

The original diameter of each specimen was6 inch.
The diameter, when under the maximum force, averages about .55 “
And when the bars broke, about50 “

The weights per square inch, as stated, all refer to the original area of the section of the bar at the place of fracture, when it was at its full diame-

ter of .6. The force under which the specimens began to yield, is about two-thirds the breaking weight.

In order to compare the iron used in the Princeton's gun with other kinds of wrought iron, the following additional specimens were tested:—

	Pounds per square in.
Russia Iron; the common flat bar—1 specimen	62644
English rolled Iron:—	
Banke's; 2 specimens from { 56896 } different bars { 56169 } Mean . . .	56532
Low-Moor; 2 specimens from { 58888 } different bars { 53317 } Mean . . .	56103
American hammered Iron:—	
Bridgewater, Massachusetts; { 58488 } 2 specimens, different bars { 49338 } Mean . . .	53913

A recapitulation of all the kinds of wrought iron tried, showing the actual and the proportional cohesive power of each, is here given:—

	Pounds per square in.	Proportional strength.
Russia Iron	62644	1.0000
English Iron:—		
Banke's	56532	.9024
Low-Moor	56103	.8955
American Iron	53913	.8605
Princeton's gun { Original bars as { 46086 } in the gun { 38595 } Same, reworked 52521		.7356 .6166 .8383

The results of this examination appear to show, that the iron used in forging the Princeton's gun was originally of an inferior quality, having only about three-fourths the strength of English Iron. It appears, also, that the original strength of the iron is considerably impaired by the process of welding it into so large a mass as that which formed the gun; the strength before and after welding being about as 6 to 5.

In numerous trials, recently made for ascertaining the tensile strength of Cast Iron, it is found that iron of such quality as is deemed suitable for cannon, will bear from 25000 to 34000 pounds per square inch. In making these trials, the specimens were carefully measured, while under the pres-

sure of different weights, and no indications of extension in length, or contraction in diameter, could be perceived in any of them. The diameter of the iron, after the rupture, appeared to be precisely the same as it was originally.

The Wrought iron, cut from the body of the Princeton's gun, began to stretch, and to contract in diameter, when under a pressure of about 25000 pounds per square inch; and that force gave it a new form, by a permanent extension and set. Cast iron, such as is now used in guns, will generally sustain a greater pressure than 25000 pounds per inch. That pressure may be regarded as the minimum limit for the strength of cast iron suitable for cannon.

All the trials referred to in the foregoing statements, for determining either the transverse or the tensile strength of the specimens, were made with the same instrument, by the same persons, and in the same manner throughout. The results are therefore stated with entire confidence in their accuracy.

W. WADE.

Boston, June 8, 1845.

Tenacity and Density of the several kinds of Iron referred to in the preceding Report.

KIND OF IRON.		POUNDS PER SQUARE INCH.			Specific gravity.
		Began to stretch.	BREAKING WEIGHT.		
			Of each bar.	Mean.	
From the Princeton's bursted gun	Original bars, previous to being forged in the gun	39789	45359	—	7.750
		37401	45359	—	—
		41380	50930	—	7.812
		40585	46155	—	—
		—	39375	—	7.739
		—	49338	46086	7.795
	Bars cut from the body of the gun	25458	40585	—	—
		23100	36606	38595	7.763
	From the same bar, after being hammered under welding heat	35320	—	52521	7.743
English Iron	Low-Moor	54113	58888	—	7.801
		46155	53317	56103	—
	Banke's	44917	56896	—	7.702
		—	56169	56532	—
Russia Iron		55704	—	62644	7.869
Bridgewater, Massachusetts		—	49338	—	—
		—	58448	—	—
		45741	49338	—	—
		44917	56500	—	—
		41557	54113	53555	—
Boston, Milldam Works		54113	—	61275	—

NOTE.—The pressure under which the bars began to stretch, was not always accurately observed. It is probable that some of the bars began to yield under a less pressure than is stated.

W. WADE.

SOUTH BOSTON FOUNDRY, September 16, 1844.

REPORT

OF

EXPERIMENTS

TO ASCERTAIN

THE DURABILITY OF 8 INCH AND 10 INCH COLUMBIADS,

BY

CONTINUOUS FIRINGS, WITH SERVICE CHARGES.

JULY, 1844.

REPORT

EXPERIMENTS

THE DEGRADATION OF A LIGN AND ITS COMPOUNDS

The purpose of these experiments was to determine the rate of degradation of lign and its compounds under various conditions. The experiments were conducted in a series of glass vessels, each containing a known quantity of the substance to be tested. The vessels were placed in a water bath maintained at a constant temperature of 37°C. The time intervals for sampling were 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912, 1073741824, 2147483648, 4294967296, 8589934592, 17179869184, 34359738368, 68719476736, 137438953472, 274877906944, 549755813888, 1099511627776, 2199023255552, 4398046511104, 8796093022208, 17592186044416, 35184372088832, 70368744177664, 140737488355328, 281474976710656, 562949953421312, 1125899906842624, 2251799813685248, 4503599627370496, 9007199254740992, 18014398509481984, 36028797018963968, 72057594037927936, 144115188075855872, 288230376151711744, 576460752303423488, 1152921504606846976, 2305843009213693952, 4611686018427387904, 9223372036854775808, 18446744073709551616, 36893488147419103232, 73786976294838206464, 147573952589676412928, 295147905179352825856, 590295810358705651712, 1180591620717411303424, 2361183241434822606848, 4722366482869645213696, 9444732965739290427392, 18889465931478580854784, 37778931862957161709568, 75557863725914323419136, 151115727451828646838272, 302231454903657293676544, 604462909807314587353088, 1208925819614629174706176, 2417851639229258349412352, 4835703278458516698824704, 9671406556917033397649408, 19342813113834066795298816, 38685626227668133590597632, 77371252455336267181195264, 154742504910672534362390528, 309485009821345068724781056, 618970019642690137449562112, 1237940039285380274899124224, 2475880078570760549798248448, 4951760157141521099596496896, 9903520314283042199192993792, 19807040628566084398385987584, 39614081257132168796771975168, 79228162514264337593543950336, 158456325028528675187087900672, 316912650057057350374175801344, 633825300114114700748351602688, 1267650600228229401496703205376, 2535301200456458802993406410752, 5070602400912917605986812821504, 10141204801825835211973625643008, 20282409603651670423947251286016, 40564819207303340847894502572032, 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5444517870735015415413993718908291383296, 10889035741470030830827987437816582766592, 21778071482940061661655974875633165533184, 43556142965880123323311949751266331066368, 87112285931760246646623899502532662132736, 174224571863520493293247799005065324265472, 348449143727040986586495598010130648530944, 696898287454081973172991196020261297061888, 1393796574908163946345982392040522594123776, 2787593149816327892691964784081045188247552, 5575186299632655785383929568162090376495104, 11150372599265311570767859136324180752990208, 22300745198530623141535718272648361505980416, 44601490397061246283071436545296723011960832, 89202980794122492566142873090593446023921664, 178405961588244985132285746181186892047843328, 356811923176489970264571492362373784095686656, 713623846352979940529142984724747568191373312, 1427247692705959881058285969449495136382746624, 2854495385411919762116571938898990272765493248, 5708990770823839524233143877797980545530986496, 11417981541647679048466287755595961091061972992, 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R E P O R T

OF

EXPERIMENTS MADE TO ASCERTAIN THE DURABILITY OF THE NEW
MODEL HEAVY 8 AND 10 INCH COLUMBIADS, BY CONTINUOUS
FIRINGS WITH SERVICE CHARGES.

THE firing was commenced with the 8 inch Columbiad, June 24, and continued to July 11, when 600 fires had been made. The vent had then become so much enlarged that the firing was discontinued.

The firing of the 10 inch Columbiad was commenced on the following day, July 12, and terminated on the 22d, when 200 fires had been made.

The charges used were, for the 8 inch gun, 10 pounds of powder, and one solid ball weighing 64 pounds; and, for the 10 inch gun, 18 pounds of powder, and one solid ball weighing 125 pounds. The powder was of the established proof range for the Service, of 250 yards, and upwards. The cartridges were closed with cartridge-blocks, and sabots were strapped to the balls; both so adjusted, that the chamber and conic junction of the bore were filled when the ball was lodged in its proper place. No wads were used. Hidden's locks, and percussion caps, were used in firing. The cord attached to the lock was passed through a barrier of logs and earth, of sufficient strength to protect the gunners in the event of the gun's bursting.

The guns, when fired, were supported on guide timbers laid in the earth; and they recoiled against a bank of sand. The recoil was 12 feet, in five fires of the 8 inch, and in three fires of the 10 inch; when the guns were moved forward to their first position. The balls were discharged into a bank of earth, and most of them were recovered and refired. The 600 fires of the 8 inch gun were made with an expenditure of 38 balls; and the

200 fires of the 10 inch gun expended 10 balls. The interior of the bores, and of the vents, were examined at stated intervals during the firing. The bores were found to be enlarged from the centre of the ball forward, and chiefly on the upper side, over the ball. The enlargement was greatest at a point half an inch in front of the ball's centre, and its termination was about three inches in front of that point. The successive enlargements of the bore, at the points where they were greatest, were as follows:—

In the 10 inch gun, the enlargement—

At the 100th fire, was		.009 inch.
At the 150th fire “		.019 “
And at the 200th fire, it was		.029 “

In the 8 inch gun, the enlargement—

At the 150th fire, was		.014 inch.
At the 200th fire “		.018 “
At the 300th fire “		.027 “
At the 400th fire “		.035 “
At the 500th fire “		.043 “
At the 600th fire “		.050 “

From these results, it appears that the bore of the 8 inch gun, in the deepest parts of the enlargement, is now a little larger than is allowed in new guns; and that the bore of the 10 inch has not yet reached that limit. 450 fires of the former, and 300 of the latter, appear to be about the number of fires which these guns will endure, before the bores become enlarged beyond the limits allowed in new guns. The bores, in all other parts, remain unaltered, and as perfect as when first fired.

The original diameters of the vents were .175 at the interior orifice, and .180 at the exterior. Their diameters, at different positions in the vent, at different periods, were as follows:—

IN THE 8 INCH GUN, AT THE				
	300th fire.	400th fire.	500th fire.	600th fire.
Interior orifice	.30	.37	.38	.58
1½ inch above orifice	.35	.39	.46	.62
In the middle	.29	.31	.39	.46
Exterior orifice	.26	.28	.35	.41

	IN THE 10 INCH GUN, AT THE		
	100th fire.	150th fire.	200th fire.
Interior orifice	.25	.26	.28
$\frac{1}{2}$ inch above orifice	.26	.28	.29
In the middle	.20	.21	.22
Exterior orifice	.19	.19	.20

The average diameter of the vent, in the 8 inch gun, is now about half an inch; and, in the 10 inch, one-fourth of an inch. The capacity of the vent is thereby enlarged in the former, eight times, and, in the latter, it is doubled.

The locks and the percussion caps succeeded very well. They rarely failed to give fire, even when the orifice of the vent had become nearly as large as the face of the hammer.

Both guns are now, apparently, as perfect and safe for service as they were before the firing, with the exception of the enlargements before mentioned.

Respectfully submitted,

W. WADE.

Boston, *July* 25, 1844.

The average diameter of the tank is 10 feet 6 inches and the height is 10 feet 6 inches. The capacity of the tank is 1000 cubic feet. The tank is made of iron plates 1/2 inch thick. The tank is lined with a layer of cement 1/2 inch thick. The tank is painted with a coat of red lead paint. The tank is supported by four legs. The tank is used for storing cement.

The average diameter of the tank is 10 feet 6 inches and the height is 10 feet 6 inches. The capacity of the tank is 1000 cubic feet. The tank is made of iron plates 1/2 inch thick. The tank is lined with a layer of cement 1/2 inch thick. The tank is painted with a coat of red lead paint. The tank is supported by four legs. The tank is used for storing cement.

The average diameter of the tank is 10 feet 6 inches and the height is 10 feet 6 inches. The capacity of the tank is 1000 cubic feet. The tank is made of iron plates 1/2 inch thick. The tank is lined with a layer of cement 1/2 inch thick. The tank is painted with a coat of red lead paint. The tank is supported by four legs. The tank is used for storing cement.

The average diameter of the tank is 10 feet 6 inches and the height is 10 feet 6 inches. The capacity of the tank is 1000 cubic feet. The tank is made of iron plates 1/2 inch thick. The tank is lined with a layer of cement 1/2 inch thick. The tank is painted with a coat of red lead paint. The tank is supported by four legs. The tank is used for storing cement.

REPORT

OF FURTHER

EXPERIMENTS

TO ASCERTAIN

THE DURABILITY OF 8 INCH AND 10 INCH COLUMBIADS,

BY

CONTINUOUS FIRINGS, WITH SERVICE CHARGES.

OCTOBER, 1844.

REPORT

REPORT OF THE COMMISSIONERS OF THE GENERAL LAND OFFICE
ON THE PROCEEDINGS OF THE COMMISSIONERS OF THE GENERAL LAND OFFICE
IN THE YEAR 1844

EXPERIMENTS

At the time of the experiments, the land was in a state of cultivation, and the soil was of a good quality. The experiments were conducted in the year 1844, and the results were as follows:

THE DEGRADATION OF THE LAND AND THE EFFECTS OF THE CULTIVATION OF THE LAND.

It is to be observed, that the land is in a state of cultivation, and the soil is of a good quality. The experiments were conducted in the year 1844, and the results were as follows:

OCTOBER, 1844.

The results of the experiments were as follows: The land was in a state of cultivation, and the soil was of a good quality. The experiments were conducted in the year 1844, and the results were as follows:

Conclusion of the report.

R E P O R T

OF

FURTHER EXPERIMENTS, MADE TO ASCERTAIN THE DURABILITY
OF THE NEW MODEL HEAVY 8 AND 10 INCH COLUMBIADS, BY
CONTINUOUS FIRING WITH SERVICE CHARGES.

At the date of the former report, July 25th, 1844, the 8 inch Columbiad had been fired six hundred times; and the 10 inch Columbiad two hundred times. The firing of the 10 inch Columbiad was resumed, with the same charges as before, on the 7th day of August, and continued to the 15th, when 600 fires had been completed. This gun was then laid aside. On the 19th of August, the firing of the 8 inch was resumed, and at the 79th fire of the next day, and the 729th fire in all, the gun burst.

Previous to resuming the fire of the 8 inch gun, its vent had been renewed with a copper bouche, one inch diameter; its full diameter extending through the iron to the surface of the chamber. The copper did not fill, entirely, the cavities formed by the previous firing. These cavities extended from the chamber upward, about three inches. An effort was made to close them, by filling them with melted tin; and the attempt was successful, apparently. But after a few fires, the tin came out unmelted. The firing was however continued, and when the gun burst, it split vertically through the middle of the vent, the copper bouche attached to one of the sides. It was thus discovered, that the cavities in the iron outside of the copper, extended from the chamber upward, four inches, and that they were, in some places, one inch wide. At each fire, these cavities must have been filled by the gas generated by the charge. And as the gas pressed upon the interior surface of the cavities with the same intensity as upon the surface of the bore, an additional strain was exerted, which, no doubt, accelerated the destruction of the gun.

The gun split in a vertical plane through the centre; the fissure passing through the breech and reinforce to the rear of the trunnions, where the line of fracture divided, diverging to the right and left, and passed out in the chase, about twelve inches in front of the trunnions. The fragments consist of three pieces only; the two equal parts of the breech and reinforce, each including one trunnion, and the chase, which remains unbroken. The lines of fracture are shown in the annexed sketch: Plate III.

The successive enlargement of the bores, and of the vents, at several points, were measured at different periods of the firing, and the results are given in the annexed tables.

The enlargement of the bores, appears to be all on the upper side, over the ball; it is greatest at a point about one inch in front of the centre of the ball, and terminates about three inches in front of that point. On examination of the 8 inch gun, after it burst, the surface of the bore over the ball, appeared to have been cut or worn away in furrows, by the flame and unconsumed portions of the charge, in the passage over the ball. The lower surface of the bore, under the ball, was smooth and planished, as if caused by the pressure of the ball upon it, in its first movements. There were no indications, in any part of the bore, of any indentations caused by the compression or bounding of the ball.

The vents were cut in a very irregular manner; sometimes, in narrow grooves which the measuring instrument could not enter. The vents therefore, were larger in many places, than the diameters given in the tables. The largest place measured in the vent of the 8 inch Columbiad, after the six hundredth fire, was $\frac{6.2}{100}$ of an inch; yet when bored out for bouching with an inch bolt, the bore did not embrace all the cavities. It is now supposed that the vent, at the three hundredth fire, when its largest measured diameter was only $\frac{3.5}{100}$ of an inch, would have required an inch bore to include all the cavities. That period of the firing, was no doubt the proper one for renewing the vent. The continuance of the firing up to six hundred rounds without bouching, was an error, which should not be repeated in any future trials of this kind. Any vent should be renewed, when so much enlarged that a bore of one inch diameter is necessary to displace all the cavities formed by the previous firing.

The vent of the 10 inch gun, now measures nearly one inch diameter; but it is probable that a two inch bore would be necessary to embrace all its

8 Inch Columbiad.



The gun split in a vertical plane through the centre; the fissure passing through the breech and reinforce to the rear of the trunnions, where the line of fracture divided, diverging to the right and left, and passed out in the chase, about twelve inches in front of the trunnions. The fragments consist of three pieces only; the two equal parts of the breech and reinforce, each including one trunnion, and the chase, which remains unbroken. The lines of fracture are shown in the annexed sketch: Plate III.

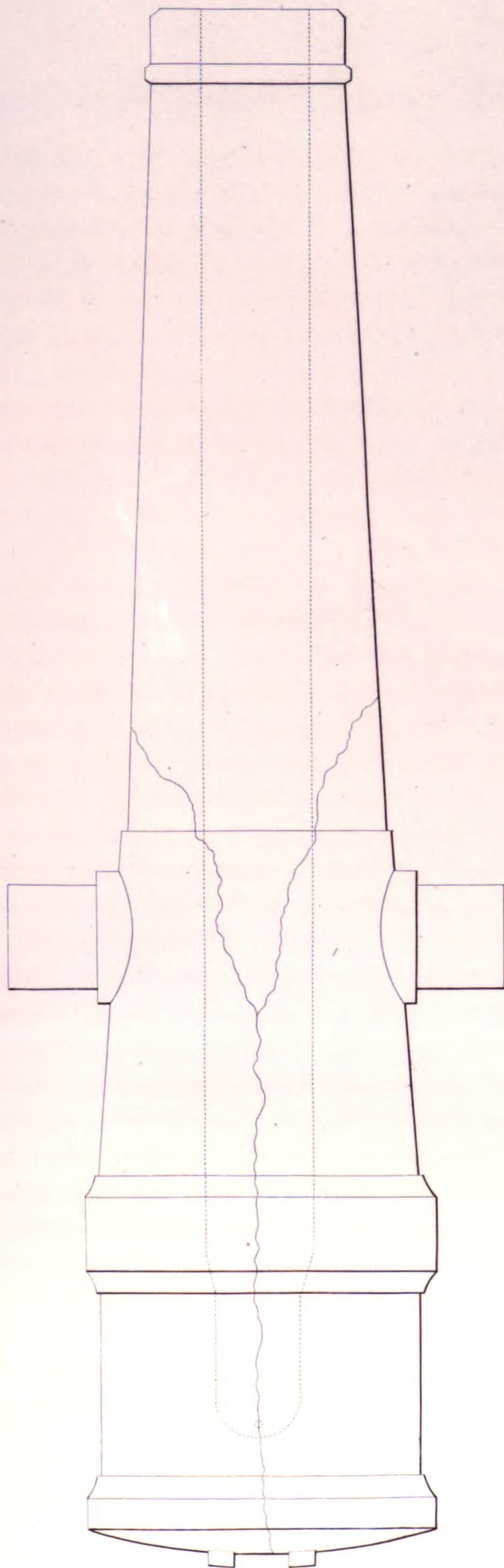
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The vents were cut in a very irregular manner; sometimes, in such grooves which the measuring instrument could not enter. The vents themselves were larger, in many places, than the diameters given in the tables. The largest vent measured in the vent of the 8 inch Columbiad, after the first hundredth fire, was $\frac{1}{10}$ of an inch; yet when bored out for the purpose of measuring, the bore did not embrace all the cavities. It is now suggested that the vent, at the three hundredth fire, when its largest measured diameter was only $\frac{1}{10}$ of an inch, would have required an inch bore to embrace all the cavities. That period of the firing, was no doubt the proper one for renewing the vent. The continuance of the firing up to six hundred rounds without renewing, was an error, which should not be repeated in any future trials of this kind. Any vent should be renewed, when so much enlargement of its diameter is necessary to displace all the cavities formed by the previous firing.

The bore of the 10 inch gun, now measures nearly one inch diameter; but it is suggested that a two inch bore would be necessary to embrace all the

8 Inch Columbiad.



Scale $\frac{1}{12}$.

The first of these is the fact that the
the second is the fact that the
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cavities. The boring of so large a hole through the body of the gun would impair its strength; and a bouche of that size would present so large a surface in the chamber, to the action of the gas from the charge, that it would be difficult to secure the bouche in its position.

Both the 8, and the 10 inch guns, have endured a service abundantly sufficient to show that their weight and strength are suitable and safe for the service for which they are designed.

The 10 inch gun remains unbroken. And although it is apparently sound, it cannot be considered a suitable gun to be reserved for future service in batteries. I, therefore, suggest, that it be fitted for projecting small bullets, perpendicular to its axis, for the purpose of measuring the force with which the charge acts at different points along the bore of the gun. The small gun, used for this purpose, in the experiments made at the Watertown Arsenal, is of too small a calibre, for determining the forces acting in large guns. If it shall not be judged proper to appropriate the gun to this service, I would then suggest its being broken up, by firing it with increasing charges, as follows: First, with a charge of 20 pounds of powder and 1 ball; and next with 22 pounds of powder and 1 ball—the last is the greatest quantity of powder which can be used without displacing the ball from its proper position in the bore—third, 18 pounds of powder and 2 balls; fourth, 20 pounds and 2 balls; fifth 22 pounds and 2 balls; then to continue the charge of 22 pounds with an additional ball at each successive fire until the gun shall burst.

It is very desirable to know what strength is yet retained by this gun, after the severe service it has already endured; and also to ascertain whether its model is duly proportioned in all its parts.

These heavy, chambered guns, are of recent date, and our knowledge of their powers, and of their safety in service, is yet limited and imperfect, and it is yet to be ascertained what weight and proportions are most suitable for them. The manner in which the 8 inch gun broke, has shown—what all our previous experience with trial guns of other calibres has shown—that the weakest point is in that part which surrounds the charge.

In my own recent experience, I have witnessed the extreme proof and bursting of five 9 pounder trial guns, made at five different foundries; and eight 6 pounder trial guns, which were made unusually light in front of the trunnions; and this heavy 8 inch Columbiad. And in all these cases, the

guns have burst in the place surrounding the charge; while the muzzle, including, generally, all in front of the trunnions, has remained unbroken. The cannon which have recently burst in ordinary practice, with service charges, have all failed in like manner. The opinion, that all the models of all our guns are faulty in this respect, seems, therefore, to be no longer a matter of doubt; but is sustained by the conclusive testimony of actual and uniform results. The further proof to extremity, of the 10 inch gun, as suggested, will serve to show whether its model is, or is not, defective.

Respectfully submitted,

W. WADE.

Boston, October 5, 1844.

Enlargement of Bores.

8 INCH COLUMBIAD.								10 INCH COLUMBIAD.							
No. of fires.	At the centre of ball.	IN FRONT OF THE CENTRE OF THE BALL.						No. of fires.	At the centre of ball.	IN FRONT OF THE CENTRE OF THE BALL.					
		Inch 0.5.	Inch 1.0.	Inch 1.5.	Inch 2.0.	Inch 2.5.	Inch 3.0.			Inch 0.5.	Inch 1.0.	Inch 1.5.	Inch 2.0.	Inch 2.5.	Inch 3.0.
150	.007	.014	.012	.009	.006	.005	.004	100	.004	.009	.007	.004	.002	.000	.000
200	.010	.018	.016	.013	.011	.008	.005	150	.007	.019	.014	.009	.006	.002	.000
250	.013	.022	.018	.014	.013	.009	.006	200	.012	.029	.026	.012	.009	.006	.000
300	.017	.027	.021	.017	.014	.010	.007	300	.019	.034	.044	.030	.019	.012	.002
350	.020	.030	.022	.018	.014	.011	.008	350	.033	.044	.053	.048	.031	.015	.003
400	.023	.035	.023	.019	.015	.012	.009	400	.027	.050	.068	.052	.044	.030	.004
450	.027	.039	.026	.021	.016	.013	.010	450	.031	.069	.081	.069	.061	.046	.005
500	.030	.043	.030	.024	.018	.014	.010	600	.042	.091	.105	.094	.091	.085	.006
550	.035	.046	.034	.027	.020	.015	.011								
600	.040	.050	.042	.031	.023	.017	.011								
729	.052	.075	.080	.058	.037	.022	.012								

The measure of the 8 inch bore, at the 729th fire, was taken after the gun had burst.

Diameters of Vents of Columbiads.

8 INCH COLUMBIAD.								10 INCH COLUMBIAD.							
Distance from the bottom of the vent.	NUMBER OF FIRES.							Distance from the bottom of the vent.	NUMBER OF FIRES.						
	300.	350.	400.	450.	500.	550.	600.		100.	200.	300.	400.	500.	600.	
At bottom	.30	.34	.37	.37	.38	.49	.58	At bottom	.25	.28	.35	.50	.70	.91	
Above 1/2 inch	.32	.36	.38	.40	.41	.50	.62	Above 1/2 inch	.26	.29	.32	.54	.72	.94	
" 1 "	.35	.37	.39	.40	.44	.53	.60	" 1 "	.33	.27	.33	.51	.73	.94	
" 2 inches	.32	.37	.38	.46	.48	.51	.62	" 2 inches	.22	.27	.34	.44	.67	.90	
" 3 "	.29	.31	.35	.39	.42	.48	.56	" 3 "	.21	.24	.30	.37	.62	.90	
" 5 "	.28	.30	.31	.32	.38	.45	.49	" 5 "	.20	.22	.28	.35	.52	.75	
" 7 "	.26	.26	.29	.33	.35	.39	.46	" 7 "	.20	.21	.27	.31	.44	.63	
" 9 "	.26	.26	.28	.31	.35	.36	.41	" 9 "	.19	.20	.26	.30	.39	.56	
								" 11 "	.19	.19	.24	.29	.37	.55	

Table with multiple columns and rows, containing numerical data and some text labels. The table is oriented horizontally on the page.

The measure of the inch, however, is not taken after the
first half inch.

THE DE BARRETT'S COLLEGE

Table with multiple columns and rows, containing numerical data and some text labels. The table is oriented horizontally on the page.

REPORT

OF FURTHER

EXPERIMENTS

TO ASCERTAIN

THE DURABILITY OF 10 INCH COLUMBIADS,

BY

CONTINUOUS FIRINGS, WITH SERVICE CHARGES.

DECEMBER, 1844.

REPORT

OF

FURTHER EXPERIMENTS MADE TO ASCERTAIN THE DURABILITY OF THE NEW MODEL HEAVY 10 INCH COLUMBIADS.

At the date of the last report, October 5, the 10 inch gun had been fired 600 times with service charges, consisting of 18 pounds of powder and one solid ball. The further proof was resumed, December 7, 1844, with a series of gradually increasing charges, arranged as follows, viz:—

First fire	.	.	.	20 pounds of powder and 1 ball.
Second fire	.	.	.	22 " " 1 "
Third fire	.	.	.	14 " " 2 balls.
Fourth fire	.	.	.	16 " " 2 "
Fifth fire	.	.	.	18 " " 2 "
Sixth fire	.	.	.	20 " " 2 "
Seventh fire	.	.	.	22 " " 2 "
Eighth fire	.	.	.	22 " " 3 "
Ninth fire	.	.	.	22 " " 4 "
Tenth fire	.	.	.	22 " " 5 "

A cartridge containing 22 pounds of powder is the largest which the chamber would contain, without displacing the ball from its proper position in the bore.

The gun was fired with the charges, and in the order above stated, up to the ninth fire inclusive. At the tenth fire, the supply of balls at the proving ground being deficient, only three were inserted; and at this fire the gun burst. It split through the vent; the vertical fissure extended from the breech forward beyond the trunnions, leaving the greater part of

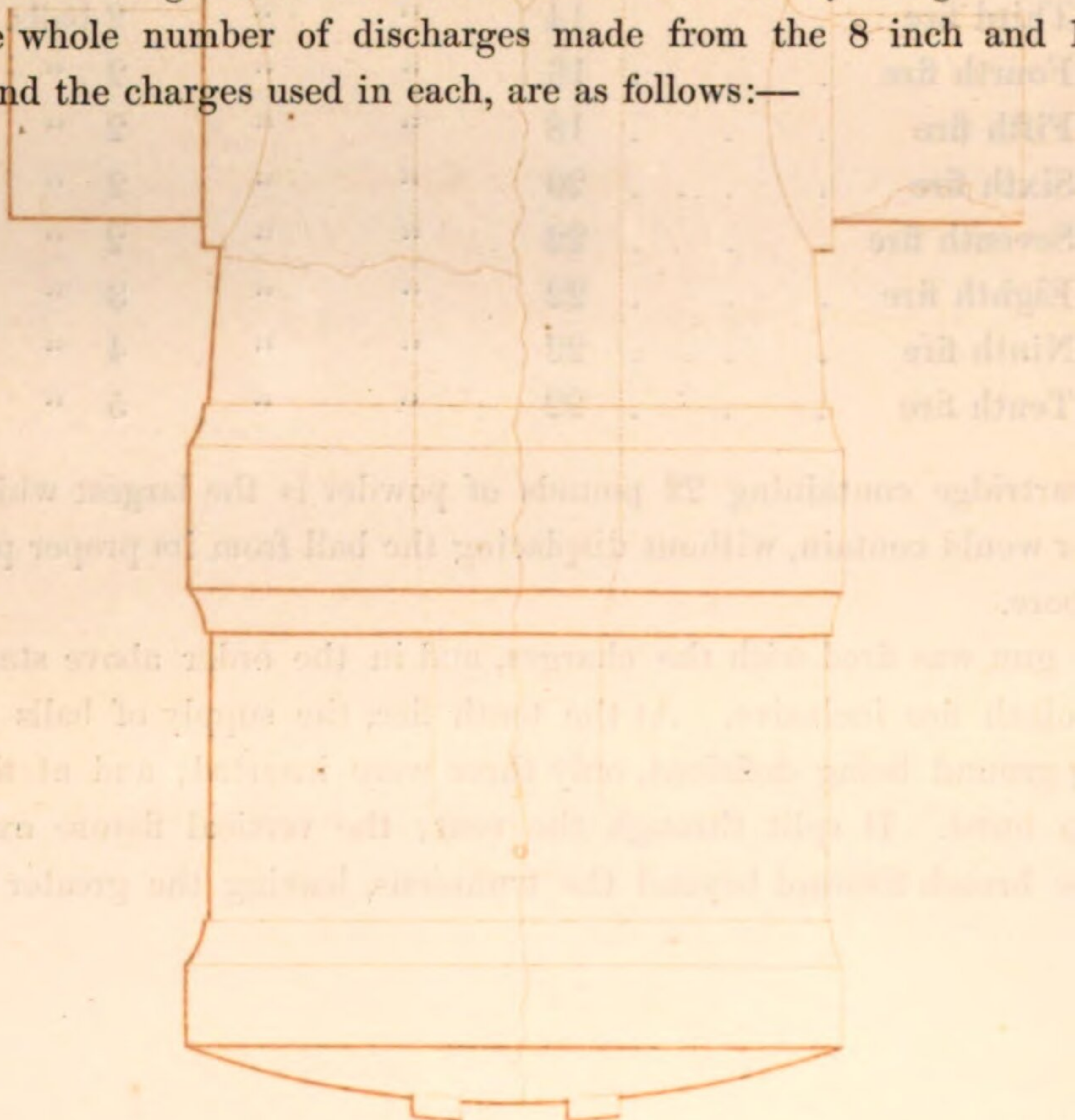
the chase entire and unbroken. The two parts of the reinforce were broken transversely in several places. The annexed sketch shows the form of the fracture. Plate IV.

The bore of the gun was much worn on the upper side, in front of the junction of the conic frustrum with the bore. The part most worn is that directly over the front half of the ball when the latter is in its proper position for firing. The lower part of the bore on which the ball rests does not appear to have been worn or indented in any appreciable quantity. No appearance of indentations, caused by the compression or bounding of the ball, were visible in any part of the bore. The enlargement over the ball was evidently the effect of wearing, caused by the gas and other products of the burned powder escaping over the ball before the latter was set in motion. The bore, in this part, was worn in longitudinal furrows, the deepest of which is about one-fourth of an inch from the original surface of the bore.

The vent was worn out into a very irregular form, and in some parts it exceeded one inch diameter.

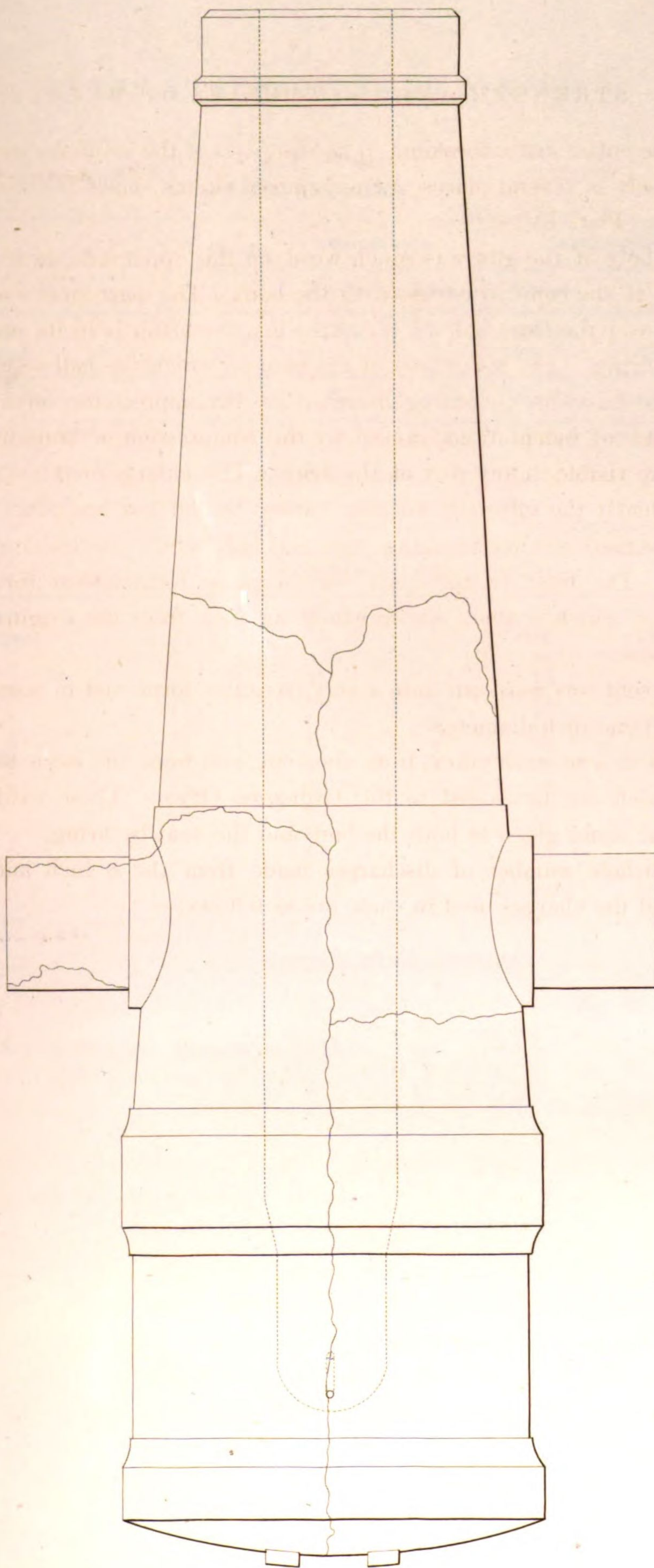
Casts in lead were taken from the vent, and from the worn part of the bore, which are forwarded to the Ordnance Office. These exhibit accurately the forms given to both the bore and the vent by firing.

The whole number of discharges made from the 8 inch and 10 inch guns, and the charges used in each, are as follows:—



Scale 1/2

10 Inch Columbiad.



Scale $\frac{1}{12}$.

8 Inch Columbiads.

	No. of fires.	CHARGES EACH.		TOTAL WEIGHT.	
		Powder.	Balls.	Powder.	Balls.
Proof charges . . .	2	15 lbs.	1	30 lbs.	128 lbs.
Service charges . . .	729	10 "	1	7290 "	46656 "
Total . . .	731	—	—	7320 lbs.	46784 lbs.

10 Inch Columbiads.

	No. of fires.	CHARGES EACH.		TOTAL WEIGHT.	
		Powder.	Balls.	Powder.	Balls.
Proof charges . . .	2	22½ lbs.	1	45 lbs.	250 lbs.
Service charges . . .	600	18 "	1	10800 "	75000 "
Extra charges	1	20 "	1	20 "	125 "
	1	22 "	1	22 "	125 "
	1	14 "	2	14 "	250 "
	1	16 "	2	16 "	250 "
	1	18 "	2	18 "	250 "
	1	20 "	2	20 "	250 "
	1	22 "	2	22 "	250 "
	1	22 "	3	22 "	375 "
	1	22 "	4	22 "	500 "
	1	22 "	3	22 "	375 "
	612	—	—	11043 lbs.	78000 lbs.

Respectfully submitted,

W. WADE.

SOUTH BOSTON FOUNDRY, December 11, 1844.

8 inch Cannon.

No. of Shot.	Amount of Shot.		Total Weight.	
	Powder.	Ball.	Powder.	Ball.
100	12 1/2 lb.	1	12 1/2 lb.	1 lb.
100	10 "	1	10 "	1 lb.
Total.	22 1/2 lb.	2	22 1/2 lb.	2 lb.

10 inch Cannon.

TABLE REPORT		EXPERIMENT 1000		NO. OF	
Pounds		Pounds		Pounds	
Pounds		Pounds		Pounds	
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100	100	1	100	1	10

REPORT

REPORT

ON THE

EXTREME PROOF OF CANNON UNDER A HYDROSTATIC PRESSURE.

OCTOBER, 1844.

REPORT

ON THE

EXTREME PROOF OF CANNON, UNDER A HYDROSTATIC PRESSURE.

AN experiment was first made upon an old condemned 18 pdr. gun; of an ancient model, about 9 feet long, and weighing 4214 pounds. The force pump and its appendages, which had been constructed for the purpose, were found to be well adapted to their several uses; and the instrument is believed to be capable of producing any degree of force which it may be desirable to obtain with it, and of measuring accurately whatever force may be exerted.

The gun was filled with water, and the force pump worked, until the pressure was raised to 7000 pounds per square inch, when the water came through the pores of the metal in several places about the neck of the gun. The water appeared on the exterior surface, exuding in very minute quantities forming in different places small mounds of white froth, which afterwards collected in drops, and fell off in small streams.

The working of the force-pump was continued until the pressure was extended to about 9000 pounds per square inch, when the gun burst.

The gun was found to have split in three lines, which, at the muzzle and for a length of 12 to 15 inches back, divided the chase into 3 equal parts. The fractures continued back to about thirty inches from the muzzle; one of them in a straight line making an even surface 21 inches long, in a plane cutting the axis of the bore. The other fractures converged towards the straight line, and came out together near its termination; thus detaching two pieces, each about 30 inches long, and 170 pounds weight. One of the pieces fell under the gun; the other was thrown off, and fell on the floor 21 feet distant. The water was discharged chiefly on the same side, and in

the same direction with the projected fragment, and some of it fell at a distance of 25 feet.

The bursting of the gun, under the pressure which was then upon it, was quite unexpected; and the manner of its bursting not less so. It was not expected that it would yield to so light a pressure, nor that the water and fragments of iron would be thrown off with such violence. All were consequently unprepared for the event; but fortunately no one was seriously injured. Several persons were deluged with the water, and some received slight contusions.

Finding the experiment, in this form, so dangerous to the persons conducting it, further trials were postponed, until other arrangements for greater security could be made. In this trial, the force pump was attached to the head block at the muzzle of the gun; and all persons assisting in the work were necessarily in that vicinity, and exposed to all fragments and water thrown from the gun. The pump was therefore detached from the head block and placed in front of the muzzle, and connected with the gun by a pipe six feet long. In this interval between the gun and the pump, a temporary barrier was placed, which served to protect the persons occupied in conducting the operations.

It was discovered, on examination after the bursting of the gun, that its bore had not been cut in the centre of the mass; the thickness of metal on the line of the straight fracture being $\frac{3}{10}$ inch less than on the opposite side. This line of fracture was carefully measured, and the average thickness of metal found to be precisely one-half the diameter of the bore. The area of the fracture is, therefore, equal to an equal length of bore multiplied by its radius; consequently the pressure per square inch of fracture, is 9000 pounds, the same as was exerted upon the water in the bore.

The gun next tried was an old 24 pdr. of a very ancient and heavy model, 8 feet long, and weight 5012 pounds. The thickness of metal, in the smallest part of the neck, is something more than half a calibre. A specimen taken from one of its trunnions, indicates iron of good quality. The pressure was extended to 9000 pounds per square inch, before any water came through the pores of the metal. The maximum pressure obtained was 9500 pounds per inch, when the experiment was discontinued. The trial of the same gun was resumed four months after, and, as before, it required a pressure of 9000 pounds per inch to force water through the

pores of the iron. When the pressure had reached this point, the water appeared at the neck of the gun, and was projected out perpendicularly in a small jet; and, soon after, several similar jets came from the face of the muzzle, in a direction nearly parallel with the axis of the bore. So much water was discharged through these jets, that the pressure within the gun soon fell off to 5000 pounds per inch; and the most vigorous efforts afterwards at the pump could not raise the pressure above that point. It appeared that the previous exertion of force had opened channels for the passage of the water through the metal which had not existed before the force was applied. The jets from the face of the muzzle are regarded as singular, for the reason that no water could enter the iron through the surface of the bore within four inches of the face of the muzzle, the packing of the tompion being within the bore that distance from the face.

Another 18 pdr. gun of the same model as the former was next tried. The pressure of the water was gradually extended up to 9860 pounds per square inch, when the gun split in two seams; one of them in a straight line parallel with the bore, the other considerably curved. Both ends of the gun remained undisturbed. The straight fissure is six feet long, and terminates at equal distances from the ends of the gun. The curved fissure is about five feet long, and terminates in a similar manner. Neither of them extends forward to the smallest part of the gun. In the annexed figures (Plate II.), the position of the straight fracture is shown on the left side of the gun above the trunnions, and the curved fracture is seen on the under side of the gun. The plane of the straight fracture cuts the axis of the bore, and its surface measures 309 square inches, showing an average thickness of metal of 4.291 inches, equal to $\frac{81}{100}$ of the calibre. The radius of the bore is 2.646, which multiplied by the length of the fracture, 72, gives an area of 190.5 inches. The pressure under which the gun burst was 9860 pounds. Hence, $\frac{9860 \times 190.5}{309} = 6079$ pounds, per square inch of fractured surface.

In this trial, the amount of friction upon the measuring piston was ascertained, when under different pressures, and was found to be as stated in the following table. These results were obtained by careful observations, and they are stated with entire confidence in their accuracy.

Pressure per Square Inch.

Weight on piston raised.	Friction.	Total pressure.
3.500 pounds.	275 pounds.	3775 pounds.
4.000 "	280 "	4280 "
4.500 "	285 "	4785 "
5.000 "	295 "	5295 "
5.500 "	300 "	5800 "
6.000 "	310 "	6310 "
6.500 "	320 "	6820 "
7.000 "	325 "	7325 "
7.500 "	335 "	7835 "
8.000 "	340 "	8340 "
8.500 "	345 "	8845 "
9.000 "	350 "	9350 "
9.500 "	360 "	9860 "

In order to obtain some idea of the relation existing between the strains produced by fired gunpowder, and by the pressure of water, another 18 pdr. gun, of the same model and weight, was tried with powder and balls. The system of proof charges adopted, was nine pounds of powder, constant, the first fire with one ball, the second with two balls, the third with three balls. The gun endured these three fires, and burst at the fourth, when the charge consisted of nine pounds of powder and four balls.

Proof bars, two feet long, were cut from each of the broken 18 pdr. guns, and were dressed in a planing machine to two inches square, and their strength and specific gravity ascertained.

The following table gives the results. No. 1 is the gun first tried and burst by hydrostatic pressure. No. 2 is the second gun, tried in like manner; and No. 3 is that which was burst by firing.

No.	Transverse strength.	Tensile strength.	HYDROSTATIC PRESSURE.		Specific gravity.	
			In the bore.	Per inch of fracture.		
No. 1	7590	27359	9000	9000	7.312	9 lbs. powder and 4 balls.
No. 2	7135	22204	9860	6079	7.328	
No. 3	7386	16849	—	—	7.384	

These guns were all of the same model and weight. No. 1 was finished on the exterior in a different manner, indicating that it had been made at a

different period, or at a different foundry from the other two. The iron in all of them is of the same general appearance—light color, hard, and close grained. They differ in degrees of hardness, No. 1 being of the least, and No. 3 the greatest; the latter was difficult to cut with the turning tool, and could not be cut at all with the file. The transverse strength of all the specimens is considerably below the average of good iron. The relative strength of each is, however, more accurately indicated in the column of tensile strength, which gives a direct and certain measure of the cohesive power of each. No. 3 is much the weakest of the three specimens tried, and either of the other two guns would no doubt have endured a greater number of fires.

The relation between the force applied in producing a fracture in cast iron, by a tensile strain in the axis of the specimen, and by that of hydrostatic pressure within the bore, appears to be somewhat greater than as three to one. If the pressure per inch on the water within the bore, be multiplied by half the circumference of the bore, instead of half its diameter, and the product be divided by the thickness of metal, the result will accord more nearly with the tensile strength.

It is very desirable to ascertain what indications of quality may be obtained by the breaking machine, that will correspond with any given proof, or endurance of a gun, by firing. There are no practical means, by which the force exerted in bursting a gun, by firing, can be measured, but when a gun is burst by hydrostatic pressure, the force used can be accurately determined. If, by the latter method, an indirect measure of the force exerted in firing can be obtained with any tolerable degree of certainty, then it will not be difficult to connect the results obtained by the breaking machine, with both.

As a further endeavor to determine the relative power of iron to resist a direct tensile force, a hydrostatic pressure, and the force of gunpowder, I propose that the 6 pdr. trial gun, which remains at the South Boston Foundry unbroken, be tried by hydrostatic pressure, and that, after it is thus broken, numerous parts of it be tried in the breaking machine. This gun has endured the heaviest proof by firing, the particulars of which are known and recorded, and it now remains apparently sound. A trial of this gun as proposed may determine another point of much interest, that of the relative powers of resistance of different thicknesses of metal, when

the bore and surface exposed to pressure remain the same. That part of this gun which surrounds the charge, is cylindrical; and the thickness of metal in this part, is equal to the diameter of the bore. The chase may be reduced to a cylinder, having the thickness of metal equal to half the diameter of the bore; and these two parts may be separately tried.

The results which may be obtained by further trials of this kind, may be of much practical utility in enabling us to judge of the quality of iron suitable for cannon, before it is melted; and also, to form a better judgment of cannon, by examinations made after they are completed.

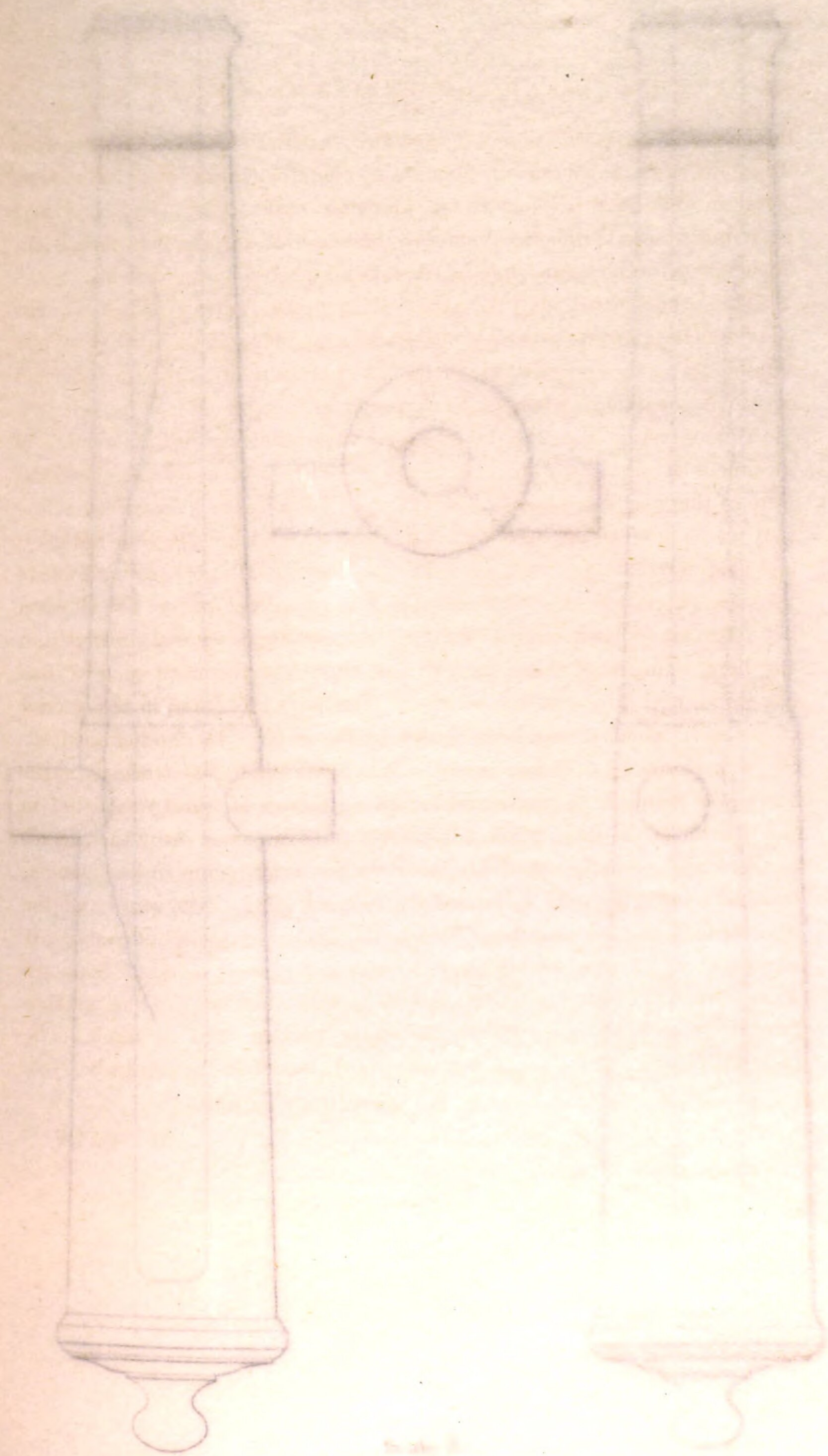
When trying the 24 pdr. gun by hydrostatic pressure, a number of specimens of pig iron were inserted in the bore. Some of the specimens were of the most open porous kinds of iron. They were all weighed before they were placed in the bore; again, immediately after they were withdrawn; and again several days after, when the specimens had become dry. Some of the pieces appeared to be a trifle heavier when first withdrawn; but all when dry returned to their original weight. Several shells were also inserted in the bore. In one of them, the eye was filled with a conical plug of hard oak-wood, well fitted and driven hard. This plug was found in the interior of the shell, where it had been forced by the water. In another shell the eye was closed by a bronze screw. When the shell was withdrawn, the screw was found to be undisturbed; but $1\frac{1}{2}$ ounces of water was found in the interior of the shell, which is supposed to have passed in by the threads of the screw. Another shell was closed with a bronze screw in like manner, and had a charging hole well filled with an oak plug. The screw and the plug both remained undisturbed; but the shell was found to contain $5\frac{1}{2}$ ounces of water, most of which, it is supposed, passed through the pores of the charging plug. From this it will be seen that none of the methods tried were sufficient to prevent the water passing into the shell. The pressure to which these shells were subjected, was 9000 lbs. per inch.

Respectfully submitted,

W. WADE.

BOSTON, *October 5, 1844.*

THE FINE CROWN



Scale 1/2 inch = 1 foot

The first and most important question is, what is the nature of the water? That part of the water which is in contact with the shell is of course of great importance, and the thickness of the film of water which is in contact with the shell is of great importance. The water may be of any temperature, and the thickness of the film of water may be of any thickness. The first question is, what is the nature of the water?

The second question is, what is the nature of the shell? That part of the shell which is in contact with the water is of course of great importance, and the thickness of the film of water which is in contact with the shell is of great importance. The water may be of any temperature, and the thickness of the film of water may be of any thickness. The first question is, what is the nature of the water?

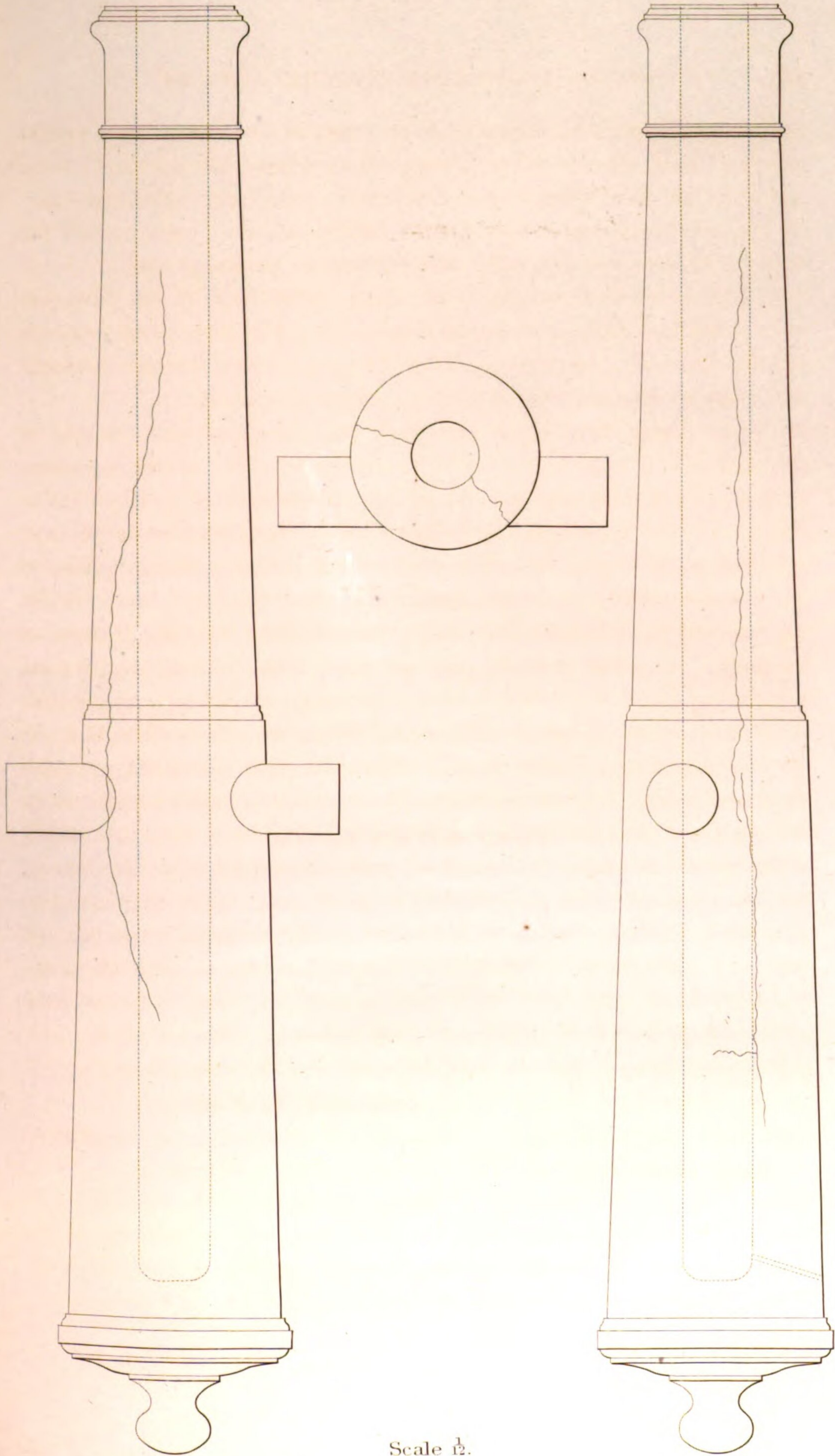
The third question is, what is the nature of the experiment? That part of the experiment which is in contact with the water is of course of great importance, and the thickness of the film of water which is in contact with the shell is of great importance. The water may be of any temperature, and the thickness of the film of water may be of any thickness. The first question is, what is the nature of the water?

Sincerely submitted,

W. WADE.

March 1, 1899.

18 Pdr. Gun.



Scale 1/2.

the bore and surface exposed to pressure remain the same. That part of this gun which surrounds the charge, is cylindrical; and the thickness of metal in this part, is equal to the diameter of the bore. The chase may be reduced to a cylinder, having the thickness of metal equal to half the diameter of the bore; and then the parts may be separately tried.

The results which may be obtained by further trials of this kind, may be of much practical utility in enabling us to judge of the quality of iron suitable for cannon, before it is casted; and also, to form a better judgment of cannon, by examination made after they are completed.

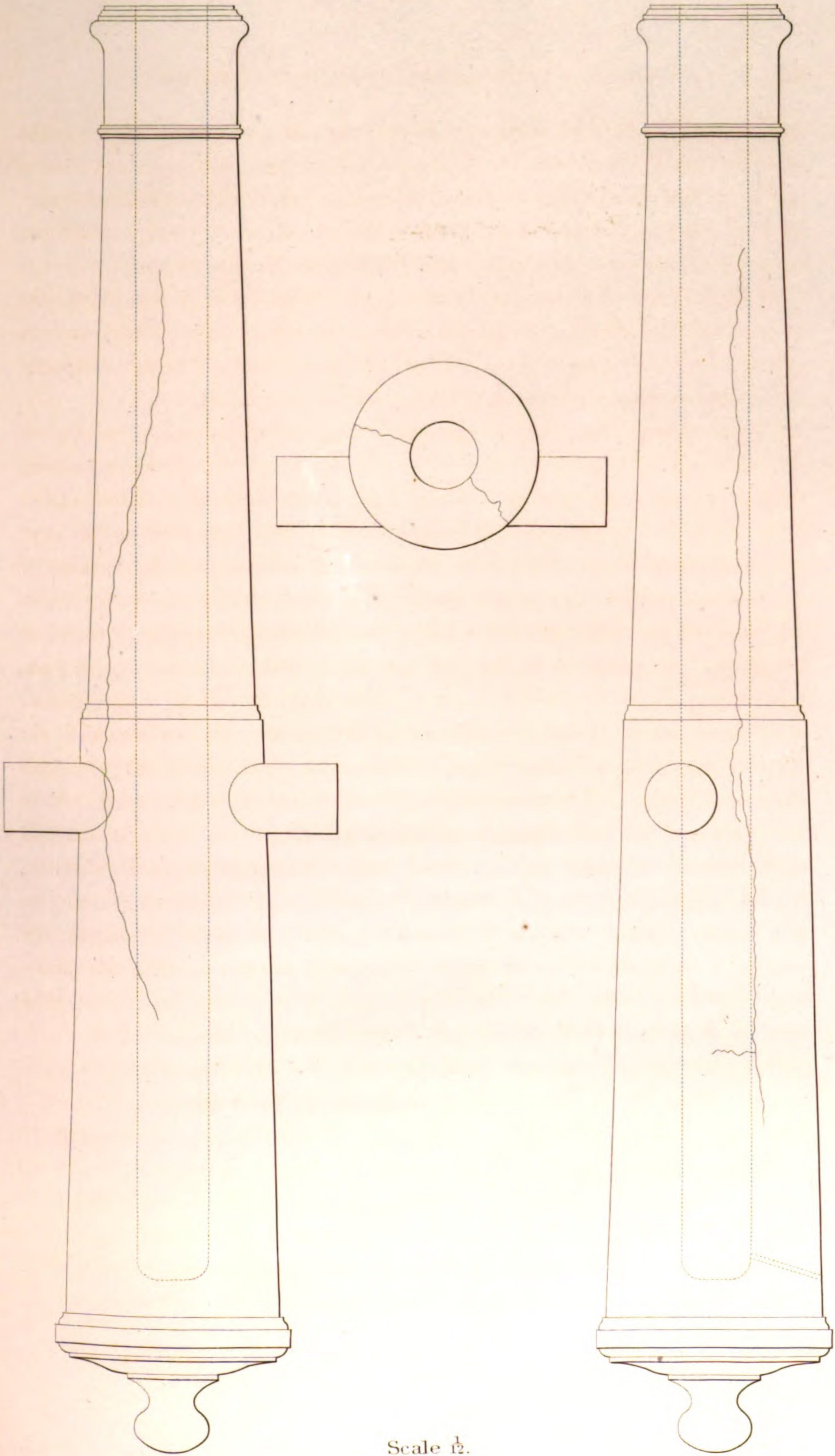
When trying the 34 lb. gun by hydrostatic pressure, a number of specimens of pig iron were inserted in the bore. Some of the specimens were of the most open porous kinds of iron. They were all weighed before they were placed in the bore; again, immediately after they were withdrawn; and again several days after, when the specimens had become dry. Some of the pieces appeared to be a trifle heavier when first withdrawn; but all when dry returned to their original weight. Several shells were also inserted in the bore. In one of them, the eye was filled with a conical plug of hard oak wood, well dried and driven hard. This plug was found in the interior of the shell, where it had been forced by the water. In another shell the eye was closed by a bronze screw. When the shell was withdrawn, the screw was found to be unaltered; but 14 ounces of water was found in the interior of the shell, which is supposed to have passed in by the threads of the screw. Another shell was closed with a bronze screw in like manner, and had a charging plug well dried with an oak plug. The screw and the plug both remained unaltered; but the shell was found to contain 54 ounces of water, most of which, it is supposed, passed through the pores of the charging plug. From this it will be seen that none of the methods tried were sufficient to prevent the water passing into the shell. The pressure to which these shells were subjected, was 9000 lbs. per inch.

Respectfully submitted,

W. WADE.

Buck. Gun. 1. 1843.

18 Pdr. Gun.



Scale 1/2.

THE

OFFICE OF THE

SECRETARY

OF THE

REPORT

OF FURTHER

TRIALS OF IRON CANNON UNDER A HYDROSTATIC
PRESSURE.

DECEMBER, 1844.

REPORT

OF

FURTHER TRIALS OF IRON CANNON BY WATER PRESSURE.

THE 6 pdr. gun No. 7, one of the number which was subjected to an extreme proof by powder and balls in March last, and which endured the highest proof and remained unbroken, has been prepared for proof by water pressure, in the manner suggested in the report of October 5.

The accompanying sketches exhibit the gun in its original form, Plate I, Fig. 1, and also, in that to which it was reduced for trial by water pressure, Plate I, Fig. 2. It is divided into three parts. The first includes all in rear of the front of the trunnions, and retains its original form. That portion of it which surrounds the cartridge is cylindrical, and the thickness of metal is there exactly equal to the diameter of the bore. The second part extends from the trunnions half way to the muzzle, and is reduced to a cylinder, the thickness of metal in which is just one-half the diameter of the bore. The third part is also cylindrical, and extends from the second to the muzzle. The thickness of metal in this part is one fourth the diameter of the bore. At the junctions of the several cylinders, a groove is cut into the metal, reducing the thickness of metal below it to two-thirds of the thickness of the cylinder in front. This reduction was made in the expectation, that in the bursting of one cylinder, the fissures would not extend into the larger one next in succession.

On the first trial, the pressure was raised to 12,400 lbs. per square inch; when the smallest cylinder, next the muzzle, burst in four fissures. The position and form of the fissures are exhibited in the accompanying sketch, Plate I, Fig. 2. Three of them extended through the whole length of this

cylinder, but none of them proceeded beyond its junction with the next cylinder.

The piston was next inserted in the second or middle cylinder, in which the thickness of metal is half a calibre. The pressure was raised to 18,500 pounds per square inch, when a leather gasket over one of the valves gave out and caused a leak, which prevented any further extension of the lever. At a subsequent trial, the packing of the measuring piston failed in like manner, when the pressure was at 19,000 pounds per inch. At the next trial, when the pressure had been extended to the same amount, the measuring lever ascended with its weight, to its maximum limit. The workmen continued the operations with the force pump, while the lever was in this checked position, and the gun burst while in the act of readjusting the weights. The precise amount of pressure, at the instant of bursting, is, therefore, unascertained. It could not, however, have been less than 19,000 pounds; and, judging from the effect produced by previous plunges of the pump piston, the pressure may be estimated at 20,000 pounds per square inch, without risk of material error.

The gun burst in three fissures; all of which passed through the whole length of the 2d cylinder, and two of them terminated with it. The other fissure extends into the reinforce about sixteen inches, passing through the right trunnion, as shown in the sketch. This seam in the reinforce prevents the trial, by water pressure, of the part in the rear, where the metal is one calibre thick. If this part had remained uninjured, an attempt would have been made to split it; but it is doubtful whether the power of the pump would have been found sufficient for the purpose. No water came through the pores of the iron, in any stage of the operations; although the thickness of metal, at the groove nearest the muzzle, was reduced to about $\frac{6}{10}$ of an inch.

Several proof bars were cut from the fragments of the gun, and tried in the breaking instrument; and the results obtained are as follows:—

Transverse Strength.

Breadth and depth of bar	2.01 inches.
Length, between supports	20. “
Breaking weight	16200 pounds.

Strength, or value of $S = 9974$.

Tensile Strength.

	Diameter.	Pounds per square in.
Bar cut from reinforce	0.85	32620
Bar cut from middle cylinder	1.25	32761
Bar cut from muzzle cylinder	0.85	34297
Mean of three trials		33226

The first two were tried on the new testing instrument, and the last on the old one.

The relation between the tenacity of iron, when measured by its power of resisting a direct tensile strain and when measured by its resistance under pressure of water, within the bores of cylinders of different thicknesses, appears from these results to be as follows:—

Tenacity.

	Pounds per inch.	Proportion.
By direct tensile force	33226	1.000
By water { Thickness equal to half of radius	24800	0.742
pressure { Thickness equal to radius	20000	0.602

In determining the resistance by water pressure, the force per square inch on the water within the bore is multiplied by the radius of the bore, and the product is divided by the thickness of the iron.

It appears from these results, that the power of resisting, in cylinders of the same quality of iron and of the same diameter of bore, but of different thickness, varies as the thickness, but in a less ratio. Hence, the increase or the diminution of the thickness of iron in a gun, does not increase or diminish the strength in like proportion. The results obtained in former trials by water pressure, with those now obtained from the 6 pdr. gun, are all given in the following table:—

Kind of iron.	BY TESTING INSTRUMENT.		BY WATER PRESSURE, PER SQUARE INCH.		Thickness of iron in parts of radius of the bore.	Ratio of resistance by water pressure, the tensile strength being the unit = 1.000.
	Transverse strength.	Tensile strength per square inch.	Within the bore.	On the area of fracture.		
18 pdr. No. 1	7590	27350	9000	9000	1.000	0.329
18 pdr. No. 2	7135	22204	9860	6082	1.621	0.273
6 pounder	9974	33226	{ 12400	24800	0.500	0.742
			{ 20000	20000	1.000	0.602

The results exhibited in this table are remarkable, chiefly, for the great difference shown in the quality of iron to be found in cannon; varying, in some instances, as 3 to 1. They show, also, that each gun maintains the same comparative character, in the order of strength, in each and all the forms of trial. The 6 pdr., for example, is highest in all the various tests; and the 18 pdr., No. 2, is lowest in all.

Respectfully submitted,

W. WADE.

Boston, December 1, 1844.

TO THE COLONEL OF ORDNANCE, WASHINGTON.

FORT PITT IRON WORKS,

Pittsburg, July 31, 1854.

COLONEL GEO. BOMFORD,

SIR: I now send reports of experiments on the extreme proof of cannon, by continuous firing with service charges, and by hydrostatic pressure, made in Boston in December last.

I have not yet made such progress, in the experiments for determining the strength of iron by the testing-machine, as I desire before coming to a satisfactory conclusion, as to the standard tests which should be insisted on, for all iron used in guns.

The sample bars, cast at the same time and with the same iron as the guns, when broken by the three forms of strain—transverse, tensile, and torsional—together with the specific gravity, do certainly give a very good measure, of the quality of the iron; by which, one may readily distinguish the differing qualities, from the worst to the best. But, nevertheless, I am not yet prepared to say precisely, what standard should be fixed upon as the minimum limit of strength for gun iron of approved quality.

I am now making an instrument to cut samples from the sinking heads of guns, which will enable us to determine the density and the tensile strength, of the iron as it exists in the gun, with greater certainty than by sample bars cast in a separate mould. My impressions at present are, that this form of test will merit more confidence than any other heretofore tried. I expect, in a few days, to make some trials of this kind.

In any revised regulations for proof and inspection, it will be necessary to provide, for limiting the indentations made in the bore by the proving balls. At the recent Navy Inspections, at West Point Foundry, and at this place, several of the guns were indented to a depth exceeding $\frac{1}{10}$ of an inch. Now this is certainly too much for good guns. Something less than this should be fixed on, as the standard limit. These indentations are no doubt caused, in part, by the softness of the iron. But I think they are influenced considerably by the kind of proof charges used. There were proved here three kinds of Navy guns; two of them with double balls (in a cluster) and *one* wad in front of the ball; the other kind, with one round shot and *two* wads, the ball lying between them. It was in the latter only

that the deep indentations were found. From this, it appears that a single ball, with a wad below, and another above it, makes a deeper indentation than a double ball with a single wad above it. This result is more striking, from the fact, that in one case of comparison, the calibre of the guns and the charges of powder used, were precisely the same; the only difference in the circumstances, was in the balls and wads. In one case, a single ball and two wads were used, which gave the deep indentations; in the other, a double ball and single wad were used, and gave slight indentations only.

I measured the 8 inch guns recently proved at West Point, after the firing, and could not find any considerable indentations in any of them; some of them were not indented at all; and none of the indentations exceeded .02. In some of the Navy guns since proved there, of the same calibre too, I understand some indentations were found to exceed .10. The guns for both Army and Navy were, I presume, of equal hardness; and the difference in the enlargements must be attributed to the different modes of proving. In this comparison, the balls used were the same, being a single round shot in both; the difference was in the powder and wads; the Navy used a larger quantity of powder, and placed a wad over the cartridge, behind the ball.

The Navy Regulations fix the maximum indentations at .02. I am of opinion that it will be difficult, if not impracticable, to keep within this limit, with such proof charges as the Navy use, without increasing the hardness of the iron to a degree bordering on brittleness. With the proof charges we use in 8 inch guns, I think it probable that the indentations will not exceed .02 or .025 in any case, provided the iron be made as hard and dense, as may safely be made without impairing its strength. But of this we can judge better after a series of close observations in the bores of guns of different qualities.

I think we may very properly reduce the variations to be allowed in the diameters of the bores. The present allowance in large guns is .04 above, and nothing below. This may I think be reduced to .025 or .03 at most. Say the average excess not to exceed .015, nor the greatest be more than .03. I believe the guns bored within the last two or three years at Boston, West Point, and this place, have been kept much within these limits.

The exterior of guns being now turned, the limits of variations of their diameters, should also be reduced. I think these may easily be brought within .025 above, and 0 below the diameter prescribed.

In fixing the limits of variation to be allowed in the dimensions of cannon, we should bear in mind what degree of accuracy can be obtained, without extraordinary expense or risk, by an experienced and skilful founder, with boring and turning lathes of iron, of the most approved construction, and who employs skilful workmen. I would narrow down the limits of variation, upon these principles, so close as to oblige the manufacturer to be vigilant and wide awake in all his operations, without subjecting him to unnecessary or extra hazard and loss. As the accuracy of the bore is the most important item in the finish of the gun, whatever limits may be assigned to its variation, they should be made imperative; and any excess beyond the prescribed limits of variation in this part, should cause the irrevocable condemnation of the gun.

But what most demands attention at present, is the ascertaining, and the prescribing, the conditions to be exacted of the raw material; and of its treatment up to, and inclusive of, the casting of the gun. For if we do not make sure of obtaining a good quality of iron, at the time of its casting into the mould, all else is useless or worse than useless. What I desire in this respect is, that the proof bars cast from the same melting as the gun, shall give, when tested by the breaking instrument, some prescribed amount of strength, and be of some stated specific gravity; the specimen from the gun head, also, to possess some stated amount of tenacity and density. Such iron as failed to reach the stated strength to be rejected.

I do not think that we are yet prepared to prescribe all the proper conditions in this respect; but I hope we may, before long, be able to do so. I have made a number of trials here, with bars obtained from the Navy guns, and have obtained some very good results. I hope to be able soon to write you more fully on this subject.

Respectfully submitted,

W. WADE.

REPORT
OF
EXPERIMENTS

MADE IN THE

PROOF OF MUSKET BARRELS UNDER HYDROSTATIC PRESSURE,

AT

WATERTOWN ARSENAL.

BY

LIEUT. P. V. HAGNER.

1844.

R E P O R T

OF THE

TRIAL OF MUSKET BARRELS UNDER THE HYDROSTATIC PRESS,
LT. P. V. HAGNER, 1844.

SIR: I have the honor to submit for your consideration, a Table of results obtained by subjecting musket barrels to pressure under the hydrostatic press. The experiments, I think, have convinced all who witnessed them, of the advantage of introducing such a proof, in connection with the powder proof, at all manufactories of small arms; as by it, defects of manufacture not developed in the finishing, or only at an advanced stage, might be made apparent after the *first boring*. It would, likewise, be of especial advantage in testing the relative value of different kinds of iron for gunbarrels, and the different processes of manufacture. In the performance of my present duties, it seems to offer the readiest means of detecting many very weak barrels, which give to the eye no indication of their weakness, while it assures us of the strength of others disfigured by what are now esteemed serious defects. Although it may not be necessary, to introduce this sort of proof in the inspection I am now making, yet, it certainly offers such important information for future use at our Armories, that I hope I may be excused for offering a few remarks upon the experiments I have already made, and for suggesting that further experiments may be made upon the subject.

A pump will not be necessary for this purpose, and thus the heavy expense of that machine may be avoided. The water may be first poured in the barrel and the pressure exerted directly upon a solid piston—a scale beam being attached to measure the pressure. If the pressure is to be

distributed alike throughout the barrel, a leather packing would close the vent and breech screw, and the barrel then filled would need but a short piston. Longer pistons and less water would be used for shorter sections of the barrel; and for the trial of any particular spot in the barrel, the breech packing could be moved forward, and as little water used as should confine the pressure to the desired space. The object in view would be to find, by the trial of good barrels, the proper maximum pressure to be applied either to the whole barrel, or to different sections of it, under which defects would be developed, without injury to the good portions, and before the expense of finishing (constituting the great cost of a barrel) should have been incurred. Now, these defects are not observed until the barrel is nearly finished, and in many cases of *old* barrels, until they burst in the hands of the men. The table accompanying this will show that the weakest spots of two New Bright Springfield barrels, which Major Ripley sent me for trial, were not previously observed, although existing in the barrels; the one a cross crack, and the other a bad weld—defects, consequently, not produced by the pressure, but made apparent by it. In the trials I made, I could only apply a pressure throughout the whole barrel alike, as the conducting pipe was but a few inches long—consequently defects existing in the thicker metal were not developed, except in cases of extremely bad iron.

The machine I would propose for use in future trials would consist *essentially*, of an upright supporting a lever, against which the piston in the muzzle of the barrel would be pressed by means of a screw, raising the barrel and its frame, and the pressure measured by weights on the long end of the lever. I would be highly gratified should you consider this subject worthy of a more extensive experiment, as I believe I have well considered the necessary details for its prosecution.

Respectfully your obedient servant,

P. V. HAGNER,

1st Lieutenant Ordnance.

Table of Results obtained with *Musket Barrels under Hydrostatic Pressure.*

DESCRIPTION OF BARRELS.				ULTIMATE PRESSURE EXERTED BY PUMP		Resulting injuries discovered by the pressure.	Thickness of metal at centre of fracture.	Calculated strength of iron per square inch tending to resist.	REMARKS.
Number.	Class.	Maker.	Date.	Upon a piston of 1 square in. surface.	Upon a piston equal to the calibre.				
				Pounds.	Pounds.				
				Existing defects causing rejection.					
12d	Waters	1827	None apparent.	5000	1875	{ Crack lengthwise, $\frac{1}{2}$ inch long, $1\frac{1}{2}$ inch from muzzle. }	.07	24.643	{ Leakage commenced at 4100 pounds; metal sound; crack barely visible. }
24th	"	1827	{ 3 bad cinder holes, 14 inches from breech. }	4800	1800	{ Crack lengthwise, 1 inch long, $4\frac{1}{4}$ ins. from muzzle. }	.08	20.700	{ Weld bad; fracture on the top; bulged open. }
34th	"	1827	{ Plug screwed in 3 inches from breech. }	4300	1612	{ Crack lengthwise, $\frac{1}{2}$ inch long, $10\frac{1}{2}$ ins. from muzzle. }	.07	21.193	Crack barely visible.
44th	"	1827	{ Cinder hole; length crack 16 inches from breech. }	3300	1237	{ Crack lengthwise, $\frac{3}{4}$ inch long, 16 inches in front of breech. }	.11	10.350	Crack slightly open.
54th	"	1827	{ Cinder hole inside, and length crack outside, about 8 ins. from muzzle. }	5050	1893	{ Crack lengthwise, about $2\frac{1}{2}$ inches long, $8\frac{1}{2}$ inches from muzzle. }	.095	18.340	{ Cinder hole and original crack connected by this crack. }
64th	"	1827	{ Cinder hole, $1\frac{1}{2}$ inch long, near vent. }	4000	1500	{ Crack lengthwise, $\frac{1}{2}$ inch long, $1\frac{1}{2}$ in. from muzzle. }	.07	19.714	Crack shows fresh fracture.
74th	"	1827	{ Plug 3 inches from breech, and flaw 12 inches from muzzle. }	4800	1800	{ Crack lengthwise, 1.1 inch long, 4 ins. from muzzle. }	.075	22.080	{ Bulged open at top; fracture fresh. }
104th	"	1827	{ Numbers of cross cracks for 16 inches from muzzle. }	—	—	Cross cracks opened.	—	—	Lever not raised.
114th	"	1827	{ Plug 3 inches from breech; unscrewed, leaving deep hole. }	5400	2025	Did not burst; thinnest metal.	.065	28.661	{ Bent so that the pressure could not be continued; bend extends 20 inches; as the barrel did not burst, the strength is greater than stated. }
122d	"	1827	None apparent.	5400	2025	{ Crack lengthwise, $2\frac{1}{2}$ ins. long, 24 ins. from breech. }	.105	17.743	Fracture fresh.
132d	"	1827	None apparent.	3800	1425	{ Crack lengthwise, $\frac{1}{2}$ inch long, $5\frac{1}{2}$ ins. from muzzle. }	.085	15.423	Slightly opened.
144th	"	1827	{ Plug 3 inches from breech; long crack, $\frac{1}{2}$ inch long, $6\frac{1}{2}$ inches from muzzle. }	3400	1275	{ Crack lengthwise, 1 inch long, $6\frac{1}{2}$ ins. from muzzle. }	.08	14.662	{ Bulged open; bad weld; not previously visible. }

NOTE.—The "plugs" mentioned, had been inserted to conceal original defects in the iron, and having been detected in the Reinspection (in progress at the time of these experiments), the barrels were assigned to the 4th Class.

Table of Results obtained with *Musket Barrels under Hydrostatic Pressure*—Continued.

DESCRIPTION OF BARRELS.			EXISTING DEFECTS CAUSING REJECTION.		ULTIMATE PRESSURE EXERTED BY PUMP		Resulting injuries discovered by the pressure.	Thickness of metal at centre of fracture.	Calculated strength of iron per square inch tending to resist.	REMARKS.
Number.	Class.	Maker.	Date.		Upon a piston of 1 square in. surface.	Upon a piston equal to the calibre.				
15	4th	Waters	1827	{ Welder's stamp too deep, and ring bore 12 inches from muzzle. }	3300	1237	{ Crack lengthwise; 3 inches long, 9 ins. from muzzle. }	.085	13.453	{ Fracture fresh; ring bore limits crack towards breech. }
16	4th	"	1827	{ Flaw 16 inches from muzzle; cross crack 22 inches from muzzle. }	5600	2100	{ Crack lengthwise, 2 inches long, 2½ ins. from muzzle. }	.08	24.150	{ Leaked, at 16 inches from muzzle, at 4000 lbs.; pressure continued; split open; fracture fresh; 22 inch cross crack did not leak, though found subsequently to extend through; thickness unequal. }
17	2d	"	1827	None apparent.	—	—	{ Crack lengthwise, 0.3 inch long, 17 ins. from muzzle. }	—	—	{ Lever not raised; crack barely visible. }
18	4th	"	1827	Flaw 7½ inches from muzzle.	3300	1237	{ Crack lengthwise, 2 inches long, 7 ins. from muzzle. }	.07	16.335	Crack barely visible.
19	4th	"	1827	Long cinder hole near vent.	5800	2175	{ Crack lengthwise, 1¼ inch long, 2 ins. from muzzle. }	.07	28.585	{ ½ inch bad weld; the fresh fracture bulged out. }
20	4th	"	1827	{ Cross crack 22 inches from muzzle. }	—	—	{ Cross crack 22 inches from muzzle. }	—	—	Lever not raised.
21	4th	"	1827		3350	1260	{ Length crack, ¾ inch long, 8 inches from muzzle. }	.075	15.410	{ Did not show on the outside at first; slightly opened. }
22	4th	"	1827	{ Seam, 2½ inches long, 4 inches from muzzle. }	—	—	{ Seam, 6 inches long, from 2½ to 8½ from muzzle. }	—	—	{ Did not show on the inside at first; lever not raised. }
1	—	Springfield	1844	{ Length crack, 1¼ in. long, commencing 9 ins. from muzzle. }	—	—	{ Cross crack, ¾ inch long, 19¼ inches from muzzle. }	—	—	{ Not previously apparent; opened under a very slight pressure. }
2	—	"	1844	{ Cross crack on outside 3 inches from breech. }	7000	2625	{ Length crack, 2 ins. long, 2½ inches from muzzle. }	.09	26.833	{ 1 inch of crack in bad weld; not to be seen at first; barrel commenced bending at 6400; bent 2 inches out of line for 25 ins. from muzzle. }
3	—	"	1844	{ Seam showed outside, 1 inch long, 24 inches from muzzle. }	6800	2550	Did not burst; thinnest metal.	.09	26.066	{ Commenced bending at 6400; had to stop pressure for fear of breaking connecting pipe. }
4	—	"	1844	Cross crack 11½ ins. from muzzle.	—	—	{ Cross crack 11½ ins. from muzzle. }	—	—	Lever not raised.

SUMMARY.

Four.—Second Class barrels, developed defects under slight pressure, which would probably have condemned them, if so tried, *before finishing*.

Seven.—Fourth Class barrels, condemned for defects, developed new defects, more injurious than those visible, and which would have been discovered, had the barrels been so tried, *before finishing*.

Eight.—Fourth Class barrels, opened under slight pressure, and thus showed that they were unfit to be finished.

One.—Fourth Class barrel, with a plug, showed better iron than any other tried.

Two.—Springfield, 1844.—Would have been condemned before finishing, and

One—of the other two, developed a concealed bad weld.

The results of trial upon all the barrels show, most satisfactorily, the great advantage of subjecting all to such a proof before finishing them. The result with the Springfield barrels shows, that *perhaps*, about 6,400 pounds will be the maximum pressure that should be exerted per square inch of piston pressed upon, or, as the pressure on the piston is proportional to the area—and the diameter of a barrel is only .69 inches— $\frac{374}{1000}$ of 6,400, or 2,400, would be about the maximum pressure to be safely exerted upon a piston fitting the bore, and inserted just within the muzzle. If it be desirous to prove the thicker portions of the barrel, the piston would be inserted to the commencement of the section to be tried, and a greater pressure should then be exerted. To find the proper safe maximum in each such case, further experiments would be required. The force tending to produce rupture under a pressure, as above stated, of 2,400 pounds at the thinnest point of the barrel, say 0.9 inch thick, would be 25,533 lbs. per square inch of metal exposed; not too strong a pressure, as, by the Ordnance Manual, the tensile force of Salisbury iron is 66,000 per square inch,

and in good iron the hydraulic strain *approximates* the tensile strength, especially where the thickness of metal is slight, compared with the diameter of the piston.

Respectfully submitted,

P. V. HAGNER,

1st Lieut. of Ordnance.

TO THE COLONEL OF ORDNANCE, WASHINGTON.

EXPERIMENTS

MADE IN

PROVING MUSKET BARRELS BY HYDROSTATIC PRESSURE,

AT

SPRINGFIELD ARMORY.

APRIL, 1846.

REPORT

OF

EXPERIMENTS, MADE IN PROVING MUSKET BARRELS BY HYDRO-
STATIC PRESSURE, AT SPRINGFIELD ARMORY, APRIL, 1846.

THE instrument which I have constructed for this purpose, is made to press, with any needful degree of force, on water contained in the bore of the barrel, and to measure accurately the force applied. The barrels are closed at the breech, and at the vent, by screws and gaskets. The bores are filled with water to any desired height, and pistons of different lengths suited to the different columns of water are used. In these trials, pistons of three different lengths have been used. One of them is suited to a column of water five or six inches high at the bottom of the barrel; another to a column of twenty-one inches, which fills the lower half of the barrel; and the other to a column of forty inches, which fills nearly the whole length of the barrel.

The following statement shows the kind of barrels tried; the pressure applied to each, and the effects produced by the pressure:—

Proof of Musket Barrels by Hydrostatic Pressure.

OBSERVED DEFECTS IN THE BARRELS.			Height of column of water.	Pres- sure on the piston.	EFFECTS PRODUCED BY THE PRESSURE.
No. of trial.	Description of defect.	Position from the breach.			
		Inches.	Inches.	Pounds.	
1	Imperfect weld; interior.	10	21	5100	{ No leak appeared; the bore enlarged $\frac{1}{10}$ inch near the head of the column.
2	{ Imperfect weld; in- terior; 4 ins. long. }	2 to 6	7	5500	{ No leak appeared until the pressure reached 5,500 lbs., when the water broke through a fissure $\frac{1}{2}$ inch long, not in the part supposed to be defective, but in another part, where no defect had previously been observed.
3	{ Iron burned, mak- ing numerous small fissures. }	37	39	{ 600 1500	{ The water escaped in globules through the observed defect. The water came out so fast that the pressure could not be increased. It leaked, also, at 22 inches from the breach, in a part where no defect had previously been observed.
			5	6100	{ No leak; the leather gasket at the breach gave out; the bore was found to be enlarged $\frac{2}{100}$ of an inch in the part occupied by the column of water.
4	{ Iron burned; many small holes. }	7	21	{ 3100 3600	{ Began to leak in the defective part. Leak not augmented; the bore expanded considerably near the head of the column of water.
5	{ Imperfect weld; ex- terior; 2 ins. long. }	33	39	2900	No leak; barrel bent considerably.
6	Cinder holes; interior.	8	21	3200	No leak; bore considerably enlarged.
7	Cinder holes; interior.	12	21	{ 3000 3200	{ No leak; enlargement of the bore barely perceptible. No leak; the bore was evidently much enlarged.
8	{ Exterior flaw; cir- cular; $\frac{3}{10}$ inch di- ameter. }	37	39	2400	No leak; barrel considerably bent.
9	Exterior cross crack.	36	39	1500	{ No leak near the observed defect, but a jet came out at 20 inches from the breach, in a part previously supposed to be sound; the leak so great that no higher pressure could be obtained.
10	Imperfect weld; interior.	9	21	3200	No leak; bore sensibly enlarged.
11	{ Large cinder holes; interior. }	15	21	3100	{ No leak appeared in the observed cinder holes, but a jet came out at 19 $\frac{1}{2}$ inches from the breach, in a part previously sound; bore enlarged.
12	{ Imperfect weld; ex- terior and interior; 3 inches long. }	2 to 5	5 $\frac{1}{2}$	6100	{ No leak; bore enlarged considerably; leather gasket at breach gave out.
13	{ Imperfect weld; ex- terior and interior; 3 inches long. }	38 to 41	40 $\frac{1}{2}$	2500	No leak; bore enlarged; barrel bent.
14	{ Barrel "scaly and dirty;" the iron appeared to be coarse, porous, and impure. }	Whole length	{ 39 21 7	{ 2000 3000 5000	{ No leak; bore enlarged perceptibly, but very slightly. No leak; bore considerably enlarged. No leak; bore considerably enlarged.

All of the barrels tried were defective, and had previously endured the usual proof of powder and balls. In all of the fourteen proved, two only, Nos. 3 and 4, leaked in the defective parts; and these defects are of the kind described as "burned iron." All of the imperfect welds, cinder holes, cracks and flaws, resisted the water pressure. Four of the barrels, Nos. 2, 3, 9 and 11, burst or leaked, in parts where no defects had previously been discovered.

The force used in each case, was greater than that exerted by the proof charge; as is evident from the barrels having yielded to the water in parts which had resisted the previous powder proof. The failures under the water proof, were caused chiefly by a permanent enlargement of the bore, and by the bending of the barrel. It appears that a pressure of 2,000 pounds on the piston, is sufficient to enlarge the bore in the thin part near the muzzle. 3,000 pounds enlarges the bore in the middle of the barrel; and 5,000 pounds enlarges it in the strongest part of the breech.

When the column of water is twenty-one inches high, and pressed with a force of 2,000 pounds, its length is diminished about half an inch; but it recovers its original length nearly, when the pressure is removed. When the column is thirty-nine or forty inches high, it is reduced $\frac{1}{2}$ inch by a pressure of 2,400 pounds. The air is carefully excluded from the barrel, and the pressure acts upon the water alone. The contraction and extension of the column of water, is attributed to a general expansion of the bore while under pressure, and to the restoration of the barrel when relieved from the pressure.

In all the trials made, the water occupied all the space between the breech pin and the piston. But if it be desirable, the force may be applied at any separate part of the barrel, and on any given length, by the use of two pistons.

The greatest force applied in any of these trials was 6,100 pounds. This was reached in two instances, in both of which the leather gasket, which is inserted between the butt of the barrel and the collar of the breech pin, gave out. As the area of the piston is $\frac{3}{4}$ inch nearly, a weight of 6,100 pounds on the piston, is equal to a pressure of 16,300 pounds per square inch, or more than one thousand atmospheres. Means may be used to secure the leather gasket, against a higher pressure if necessary. But it is believed that a pressure of even 5,000 pounds will be quite sufficient for

all practical purposes, as that pressure will produce a permanent enlargement of the bore, in the strongest part of any barrel—an effect never produced by ordinary proof charges, in a sound barrel.

These trials were made for the purpose, chiefly, of ascertaining the power and working qualities of the instrument; and the results are entirely satisfactory. The force is applied by a direct mechanical pressure, without any forcing pump. The instrument is worked with ease and certainty; it gives with facility any desired pressure; and measures accurately whatever force is applied. No difficulty is found in packing the pistons, nor in the practical workings of the instrument in any other respect. Its power may be applied through the whole length of the bore at once, or it may be applied on any separate part, and is sufficient to destroy the barrel in any part.

Further trials are, however, necessary, before the application and use of the instrument, in testing barrels, generally, can be properly defined. It is evident, from the few results thus far obtained, that it will be useful as an auxiliary to the present methods of proof. These results exhibit, in some instances, material defects which were previously invisible. And in other instances they prove that visible, and supposed fatal defects, were visual blemishes only, and did not lessen the strength or safety of the barrel.

Further experiments, made with due care and attention, may serve to show that musket barrels may be advantageously tested by this method alone; and that the powder proof may be omitted. The instrument certainly possesses all the power necessary for this purpose; and accurate observations in future trials, may show that it will be advantageous to use it.

In the several kinds of iron which are used in making musket barrels, it is probable, that considerable difference exists in their qualities of ductility and rigidity, and of hardness and softness. These qualities may be measured by the use of this instrument. Soft ductile iron will expand in a barrel, and become permanently enlarged in its bore, under a less pressure than hard rigid iron will do. In order to make trials for this purpose, instruments capable of measuring minute variations, in the diameter of the bore, and of exterior diameters, should be first provided. In the making of these trials, there were no suitable instruments of this kind at hand; but rough measures were taken and computed. And it appears from the results

of trial No. 14, which was tested in three different places, that a tensile force of about 20,000 pounds was sufficient to cause a permanent expansion of the bore. This indicates iron of an inferior quality.

Respectfully submitted,

W. WADE.

SPRINGFIELD, 30th April, 1846.

TO THE COLONEL OF ORDNANCE, WASHINGTON.

REPORT

OF

EXPERIMENTS

MADE BY

MAJOR WADE, UNDER DIRECTION OF COLONEL BOMFORD,

IN

FIRING A 12 INCH COLUMBIAD PROPOSED BY HIM.

BOSTON, 1846.

REPORT

EXPERIMENTS
WITH THE 12 INCH COLUMBIAD PROJECTED BY HIM
WITH THE 12 INCH COLUMBIAD PROJECTED BY HIM
WITH THE 12 INCH COLUMBIAD PROJECTED BY HIM

EXPERIMENTS

1841. 12. 1. The object of these experiments was to determine the effect of the elevation of the gun on the range of the shot. The gun was elevated at angles of 15, 30, 45, and 60 degrees. The shot was fired at a distance of 1000 yards. The results were as follows:

Elevation	Range
15°	1000
30°	1000
45°	1000
60°	1000

The results show that the range of the shot is not affected by the elevation of the gun. This is due to the fact that the shot is fired at a distance of 1000 yards, which is the maximum range of the gun. The results also show that the shot is fired at a distance of 1000 yards, which is the maximum range of the gun.

REPORT

OF

EXPERIMENTS MADE UNDER DIRECTION OF COLONEL BOMFORD
WITH THE 12 INCH COLUMBIAD PROPOSED BY HIM AND CAST AT
SOUTH BOSTON FOUNDRY.

BOSTON, *October 26, 1846.*

COL. G. TALCOTT.

SIR: Since the receipt of your letter of 3d instant, we have been engaged in firing the 12 inch Columbiad with different charges of powder, and at different elevations. We have tried the fuzes in bronze cases, and also those inserted in the body of the shell, and do not find any material difference in their results.

Among the trials made, there were three fires at 35° elevation, and with cartridges of 20 pounds. The fuzes were made for 29", 35", and 45"; the latter in a bronze case. The shell with the fuze of 29" was loaded with a blowing charge only, and exploded in the air at 27" flight. The two other shells were loaded with a full bursting charge of 7 pounds, and both exploded; one of them, the 35", two or three seconds before it reached the ground, and the other, one or two seconds after it struck. The range of the former was 5,142 yards, and of the two latter 5,441 and 5,405 yards.

I mention these particular trials, because their results were ascertained in a certain and unquestionable manner. I was myself at the observing station near the places where the shells fell. Other persons were much nearer, and almost within range of the broken fragments, and the results were distinctly seen by all.

I endeavored to ascertain whether the 45" fuzes would resist being extinguished on striking the water, when fired horizontal, but was unsuccessful. The shells went down in deep water, where the bursting, if any occurred,

could not be seen nor known. It is not material, however, whether 45" fuzes can be made to resist the water in ricochet fires, because in such fires the time of flight cannot be extended beyond 20"; and the useful effect of shells in ricochet fire most probably terminates within 16". Fuzes of the same length, made to burn for a short time, have much greater power to resist premature extinguishment, than those which are made to burn for an extreme flight.

It appears to me that fuzes made in either way, that of inclosing them in bronze cases, as devised by Colonel Bomford, or that of inserting them in the body of the shell, as devised by Mr. Alger, may be relied on for either longer or shorter ranges. And I have no doubt, that either of those methods is greatly superior to the ancient method of driving the fuzes in cases of wood. Some trials of the latter were recently made here by Commodore Jones, with shells which had been fitted with wood fuzes at Fort Munroe Arsenal some years ago, and which had made a voyage to the Pacific. The shells were fired with light charges. The fuzes were marked 12" and 15". One shell burst at the muzzle of the gun, one within 150 yards of the gun, another at 6" flight, and the fourth did not explode.

The fuzes devised both by Colonel Bomford and Mr. Alger, are provided with a safety guard, which will prevent an explosion of the shell, if the fuze should happen to be undesignedly ignited in the batteries. This has been satisfactorily tested by igniting and burning a fuze in a loaded shell, without igniting the bursting charge; and then, without further alteration than the insertion of another fuze of the same kind, the same shell was discharged from the gun and burst at the time designed.

I do not however attach much importance to this property of these fuzes, for the reason that I believe the exterior cap of lead which is used in both kinds, is a sufficient safeguard against any premature ignition of the fuze. The addition of any interior contrivance is but adding another delicate intricacy in the construction of fuzes, and another to the numerous conditions, which must in practice be fulfilled to insure success.

Respectfully submitted,

W. WADE.

Journal of Shell Firing with 12 inch Columbiad. Boston, 1846.

DATE.	Order of fire.	Charge of powder.	Weight of shells.	Weight of powder in shells.	Angle of elevation.	Kind of fuse.	Time of flight.	Explosion of shells.	Range.	Recoil of carriage.	REMARKS.
	No.	Pounds.	Pds.	Pds. Ozs.	Degrees.		Secs.		Yards.	Inches.	
Oct. 5	1	20	172	—	0	—	—	—	—	84	Recoiled the whole length of chassis, to rear hurters.
" 5	2	20	172	.12	0	Paper	—	Succeeded	—	84	
" 7	3	20	199	.12	22	Bronze	20	Succeeded	—	34	
" 7	4	20	172	.10	22	Bronze	20	Succeeded	—	25	
" 7	5	20	169	.10	22	Bronze	20	Succeeded	4280	20	The shells from the 4th, 5th, 6th, 8th, and 10th fires were recovered, and the ranges were measured, and were 4186, 3947, 4245, 4508, and 4513 = mean 4280 yards.
" 7	6	20	171	.10	22	Bronze	20	Succeeded	—	21	
" 7	7	20	172	6.	0	Bronze	—	Succeeded	—	40	
" 7	8	20	174	.10	22	Paper	20	Succeeded	—	22	
" 7	9	20	171	7.	0	Paper	—	Succeeded	—	42	The ranges of 1, 2, 3, 7, and 9 were not ascertained.
" 7	10	20	174	.10	22	Paper	20	Succeeded	—	22	
" 10	11	20	174	.10	25	Paper	—	Succeeded	4960	27	
" 10	12	20	171	.10	25	Paper	—	Failed	4647	28	
" 10	13	20	172	.10	25	Paper	—	Succeeded	4548	24	{ This shell, No. 12, was recovered, and it was then ascertained that its lead cap had not been removed. The same shell was used in the 83d fire.
" 10	14	20	171	.10	30	Paper	—	Succeeded	4990	16	
" 10	15	20	173	6.	30	Paper	—	Failed	5020	14	
" 10	16	20	171	6.	30	Bronze	—	Failed	5003	15	
" 10	17	20	179	7.	35	Paper	32	Succeeded	5441	13	This shell fell in a soft, inaccessible marsh. This shell fell in a soft, inaccessible marsh. Burst into fragments 1'' before it struck.
" 10	18	20	171	1.	35	Paper	31	Succeeded	5172	14	
" 10	19	20	172	7.	35	Bronze	33	Succeeded	5405	15	
" 10	20	20	173	.10	39	Bronze	33	Failed	5030	13	
" 14	21	20	171	.10	39	Bronze	33	Succeeded	4791	20	NOTE.—The shells which were not seen to explode, or the explosion of which were not ascertained by a recovery of the shell, are noted as having <i>failed</i> , although they may have exploded unseen, in deep water or soft marsh.
" 14	22	20	172	.10	39	Bronze	33	Succeeded	5192	21	
" 14	23	25	173	.10	30	Paper	33	Succeeded	5258	33	
" 14	24	25	172	.10	30	Paper	33	Succeeded	5116	33	
" 14	25	25	171	.10	30	Paper	33	Succeeded	4933	27	
" 14	26	25	173	.10	35	Paper	33	Failed	5360	24	
" 14	27	25	172	.10	35	Bronze	31½	Failed	5296	38	
" 15	28	25	171	.10	35	Bronze	32	Succeeded	5571	41	
" 15	29	25	173	.10	39½	Bronze	—	Failed	5360	35	

Journal of Shell Firing with 12 inch Columbiads—Continued.

DATE.	Order of fire.	Charge of powder.	Weight of shells.	Weight of powder in shells.	Angle of elevation.	Kind of fuse.	Time of flight.	Explosion of shells.	Range.	Recoil of carriage.	REMARKS.
1846.	No.	Pounds.	Pds.	Pds. Ozs.	Degrees.		Secs.		Yards.	Inches.	
Oct. 15	30	25	172	.10	39 $\frac{3}{4}$	Paper	—	Failed	5365	31	At this fire, the breech of the gun bounded up 25 degrees.
" 15	31	25	172	.10	39 $\frac{3}{4}$	Bronze	36	—	5551	26	
" 15	32	20	173	.10	37	Bronze	30 $\frac{1}{2}$	Succeeded	5197	24	
" 15	33	20	172	—	37	—	31 $\frac{1}{2}$	—	5336	24	These shells were not loaded.
" 15	34	25	169	—	37	—	—	—	5402	26	
" 20	35	20	151	.10	22	Paper	—	Failed	4657	16	{ At the 36th fire, the upper carriage rested on its front wheels, which rolled in the recoil. The carriage went back against the hurters, and bounded forward 2 feet.
" 21	36	20	173	.10	0	Paper	15	Succeeded	2500	84	
" 21	37	20	168	.10	0	Paper	17	Succeeded	2926	45	
" 21	38	20	168	.10	0	Paper	16	Succeeded	2884	45	This and the following shells were not loaded.
" 21	39	20	149	.10	0	Paper	19 $\frac{1}{2}$	Succeeded	3332	40	
" 21	40	25	174	.10	0	Paper	18	Succeeded	3075	82	
" 21	41	25	170	.10	0	Paper	16	Succeeded	2825	81	This shell skipped on the water 36 times.
" 21	42	25	169	.10	0	Paper	14	Succeeded	2872	78	
" 21	43	20	174	.10	10	Paper	12	Succeeded	2871	37	
" 21	44	20	167	.10	10	Paper	10 $\frac{1}{2}$	Succeeded	2699	34	This shell broke into pieces when it first struck the water.
" 21	45	20	169	.10	10	Paper	10 $\frac{1}{2}$	Succeeded	2740	35	
" 21	46	25	170	.10	10	Paper	11 $\frac{1}{2}$	Succeeded	2953	44	
" 21	47	25	168	.10	10	Paper	11	Succeeded	2779	43	This and the following shells were not loaded.
" 21	48	25	165	.10	10	Paper	12	Succeeded	2912	44	
" 21	49	25	169	.10	15	Paper	14	Succeeded	3466	35	
" 21	50	25	168	.10	15	Paper	16	Succeeded	3651	37	This shell broke into pieces when it first struck the water.
" 21	51	25	170	.10	15	Paper	15	Succeeded	3508	37	
" 21	52	25	154	—	0	Paper	18	—	3029	49	
" 21	53	25	155	—	0	—	20	—	3355	46	This shell broke into pieces when it first struck the water.
" 21	54	25	154	—	10	—	13 $\frac{1}{2}$	—	3134	38	
" 15	55	25	154	—	15	—	18 $\frac{1}{2}$	—	4108	36	
Nov. 3	56	20	139	—	0	—	19 $\frac{1}{2}$	—	3290	43	This shell broke into pieces when it first struck the water.
" 3	57	20	124	—	0	—	16	—	2730	41	
" 5	58	20	124	—	0	—	16	—	2716	48	
" 5	59	25	129	—	0	—	—	—	—	52	

Nov. 5	60	25	130	—	0	—	—	18	—	—	3039	50
" 5	61	20	140	—	10	—	—	14½	—	—	3279	41
" 5	62	20	140	—	10	—	—	14½	—	—	3386	42
" 5	63	25	142	—	10	—	—	14½	—	—	3326	51
" 5	64	20	171	—	15	—	—	16½	—	—	3879	46
" 5	65	20	170	—	15	—	—	15½	—	—	3685	48
" 5	66	20	169	—	15	—	—	16	—	—	3630	47
" 5	67	20	144	—	15	—	—	17½	—	—	3800	37
" 5	68	20	145	—	15	—	—	18½	—	—	4038	35
" 5	69	25	145	—	15	—	—	18½	—	—	4095	42
" 5	70	20	146	—	35	—	—	—	—	—	5412	22
" 5	71	20	150	—	35	—	—	—	—	—	5407	24
" 5	72	25	168	—	35	—	—	—	—	—	5431	34
" 5	73	25	168	—	35	—	—	—	—	—	5346	38
" 5	74	20	130	—	35	—	—	—	—	—	5304	19
" 5	75	20	130	—	35	—	—	—	—	—	5200	16
" 5	76	25	130	—	35	—	—	—	—	—	5300	18
" 5	77	25	132	—	35	—	—	—	—	—	5334	13
" 5	78	25	180	—	35	—	—	—	—	—	5514	31
" 5	79	25	178	—	35	—	—	—	—	—	5774	32
" 5	80	25	167	—	37	—	—	32	—	—	5344	37
" 5	81	25	179	—	39½	—	—	36	—	—	5449	23
" 5	82	25	180	—	39½	—	—	—	—	—	5780	34
" 5	83	25	173	.10	39½	Paper	36	Succeeded	5495	25	5758	26
" 5	84	25	172	—	39½	—	—	—	—	—	5660	38
" 6	85	28	180	—	35	—	—	—	—	—	5682	34
" 6	86	28	180	—	35	—	—	—	—	—	5800	24
" 6	87	28	181	—	39	—	36	—	—	—	5723	23
" 6	88	28	182	—	39	—	—	—	—	—	—	—
" 6	89	20	—	6.	0	Paper	—	Failed	—	—	—	—
" 6	90	20	—	6.	0	Paper	—	Failed	—	—	—	—
" 6	91	20	—	6.	10	Paper	—	Succeeded	—	—	—	—
" 6	92	20	—	6.	10	Paper	—	Succeeded	—	—	—	—
" 6	93	20	—	6.	15	Paper	—	Succeeded	—	—	—	—

This shell broke when it struck the water.

{ Shell 83 had been previously fired with its lead cap un- removed. It had remained in damp ground several days, and was now fired with the same fuse.

These shells had been previously fired, and recovered from soft, wet ground. After 89 and 90 had been fired and failed, the remainder were examined, and found to contain mud and water; the wet fuses were then replaced by others, and all then took effect.

Statement of the Foregoing Particulars arranged in Classes.

CHARGE 20 POUNDS.						CHARGE 25 POUNDS.					
Eleva- tion.	No. of fire.	Weight of shell.	Range.	Time of flight.	Recoil of carriage.	Eleva- tion.	No. of fire.	Weight of shell.	Range.	Time of flight.	Recoil of carriage.
		Pounds.	Yards.	Seconds.	Inches.			Pounds.	Yards.	Seconds.	Inches.
0°	36	173	2500	15	84	0°	40	174	3075	18	82
	37	168	2926	17	45		41	170	2825	16	81
	38	168	2884	16	45		42	169	2372	14	78
	39	149	3332	19½	40		52	154	3029	18	49
	56	139	3290	19½	43		53	155	3355	20	46
	57	124	2730	16	41		59	129	—	—	52
	58	124	2716	16	48		60	130	3039	18	50
10°	43	174	2871	12	37	10°	46	170	2953	11½	44
	44	167	2699	10½	34		47	168	2777	11	43
	45	169	2740	10½	35		48	165	2912	12	44
	61	140	3279	14½	41		54	154	3134	13½	38
	62	140	3386	14½	42		63	142	3326	14½	51
15°	64	171	3879	16½	46	15°	49	169	3466	14	35
	65	170	3685	15½	48		50	168	3651	16	37
	66	169	3630	16	47		51	170	3508	15	37
	67	144	3800	17½	37		55	154	4108	18½	36
	68	145	4038	18½	35		69	145	4095	18½	42
22°	4 to 10	170	4280	20	24						
	35	151	4657	—	16						
25°	11	174	4960	—	27						
	12	171	4647	—	28						
	13	172	4548	—	24						
30°	14	171	4990	—	16	30°	23	172	5258	—	33
	15	179	5020	—	14		24	173	5116	—	33
	16	177	5003	—	15		25	171	4993	—	37
35°	17	180	5441	32	13	35°	78	180	5514	—	31
	19	179	5405	33	15		79	178	5774	—	32
	18	172	5172	31	14		26	173	5360	—	24
	70	146	5412	—	22		27	172	5296	31½	38
	71	150	5407	—	24		28	171	5571	32	41
	74	130	5304	—	19		72	168	5431	—	34
	75	130	5200	—	16		73	168	5346	—	38
							76	130	5300	—	18
							77	132	5334	—	13

NOTE.—Shells of nearly equal weight are grouped together, and division lines drawn between groups, for convenience in arranging the "Statement of Mean Results," q. v. page 118.

Statement of the Foregoing Particulars arranged in Classes—Continued.

CHARGE 20 POUNDS.						CHARGE 25 POUNDS.					
Eleva- tion.	No. of fire.	Weight of shell.	Range.	Time of flight.	Recoil of carriage.	Eleva- tion.	No. of fire.	Weight of shell.	Range.	Time of flight.	Recoil of carriage.
		Pounds.	Yards.	Seconds.	Inches.			Pounds.	Yards.	Seconds.	Inches.
37°	32	173	5197	30½	24	37°	34	169	5402	—	26
	33	172	5336	31½	24		80	167	5344	32	37
39°	20	173	5030	—	13	39¾°	81	179	5449	36	23
	21	171	4971	—	20		82	180	5780	—	34
	22	172	5182	—	21		29	173	5360	—	35
							30	172	5365	—	31
							31	172	5551	36	26
							83	173	5495	36	25
							84	172	5758	—	26
Charge 28 pounds						35°	85	180	5660	—	38
							86	180	5682	—	34
						39°	87	181	5800	36	24
							88	182	5723	—	23

Statement of Mean Results.

Elevation.	CHARGE 20 POUNDS.				CHARGE 25 POUNDS.			
	Weight of shell.	Range.	Time of flight.	Recoil.	Weight of shell.	Range.	Time of flight.	Recoil.
	Pounds.	Yards.	Seconds.	Inches.	Pounds.	Yards.	Seconds.	Inches.
0°	170	2770	16	58	171	2757	16	80
	144	3306	19½	42	154	3192	19	48
	124	2723	16	44	130	3309	18	50
10°	170	2770	11	35	168	2881	11½	44
	140	3333	14½	42	148	3230	14	45
15°	170	3731	16	47	169	3542	15	36
	144	3919	17	36	149	4101	18½	39
22°	170	4280	—	24	—	—	—	—
	151	4657	—	16	—	—	—	—
25°	172	4718	—	26	—	—	—	—
30°	176	5004	—	15	172	5102	—	31
35°	179	5423	32½	14	179	5644	—	31
	172	5172	31	14	172	5409	31¾	34
	148	5409	—	23	168	5388	—	36
	130	5252	—	18	131	5317	—	16
37°	172	5266	31	24	168	5373	32	32
39°	172	5064	—	18	—	—	—	—
39¼°	—	—	—	—	{ 180	5615	36	28
	—	—	—	—	{ 172	5506	36	29
Charge 28 pounds			Elevation.		180	5671	—	36
			{ 35° 39°		181	5761	36	24

12 inch Columbiad Firing with 12 inch Shells. November, 1846.

CHARGE 20 POUNDS.					CHARGE 25 POUNDS.					
Elevation.	Weight of shells.	RANGE IN YARDS.		Time of flight.	Elevation.	Weight of shells.	RANGE IN YARDS.		Time of flight.	
		Each.	Mean.				Each.	Mean.		
Degrees.	Pounds.			Seconds.	Degrees.	Pounds.			Seconds.	
Horizontal	173	2500	2770	16	Horizontal	174	3075	2757	16	
	168	2926				170	2825			
	168	2884				169	2372			
	149	3332	3311	19½		154	3029	3192	19	
	139	3290				155	3355			
	124	2730				129	Broke			
124	2716	2723	16	130	3039	3039	18			
10°	174	2871	2770	11	10°	170	2953	2881	11½	
	167	2699				168	2777			
	169	2740				165	2912			
	140	3279	3333	14½		154	3134	3230	14	
	140	3386				142	3326			
15°	171	3879	3731	16	15°	169	3466	3542	15	
	170	3685				168	3650			
	169	3630				170	3508			
	144	3800	3919	18		154	4108	4101	18½	
	145	4038				145	4095			
22°	170	—	4280	20						
	151	—	4657	—						
25°	174	4960	4718	—						
	171	4647								
	172	4548								
30°	171	4990	5004	—	30°	172	5258	5102	—	
	173+6	5020				173	5116			
	171+6	5003				171	4933			
35°	174+6	5441	5339	32	35°	180	5514	5644	—	
	171+1	5172				178	5774			
	172+7	5405				173	5360			
	146	5412	5409	—		172	5296	5409	32	
	150	5407				171	5571			
	130	5304	5252	—		168	5431	5388	—	
	130	5200				168	5346			
						130	5300	5317	—	
						132	5334			
37°	172	5197	5266	31	37°	169	5402	5373	32	
	173	5336				167	5344			

CHARGE 20 POUNDS.				
Elevation.	Weight of shells.	RANGE IN YARDS.		Time of flight.
		Each.	Mean.	
Degrees.	Pounds.			Seconds.
39°	$\left\{ \begin{array}{l} 173 \\ 171 \\ 172 \end{array} \right.$	$\left\{ \begin{array}{l} 5030 \\ 4971 \\ 5192 \end{array} \right.$	5064	—

CHARGE 25 POUNDS.				
Elevation.	Weight of shells.	RANGE IN YARDS.		Time of flight.
		Each.	Mean.	
Degrees.	Pounds.			Seconds.
39°	$\left\{ \begin{array}{l} 173 \\ 172 \\ 172 \\ 173 \\ 172 \\ 179 \\ 180 \end{array} \right.$	$\left\{ \begin{array}{l} 5360 \\ 5365 \\ 5551 \\ 5495 \\ 5758 \\ 5449 \\ 5780 \end{array} \right.$	5506	36
			5615	—

CHARGE 28 POUNDS.				
Elevation.	Weight of shells.	RANGE IN YARDS.		Time of flight.
		Each.	Mean.	
Degrees.	Pounds.			Seconds.
35°	$\left\{ \begin{array}{l} 180 \\ 180 \end{array} \right.$	$\left\{ \begin{array}{l} 5660 \\ 5682 \end{array} \right.$	5671	—
39°	$\left\{ \begin{array}{l} 181 \\ 182 \end{array} \right.$	$\left\{ \begin{array}{l} 5800 \\ 5723 \end{array} \right.$	5761	36

93 fires in all { 79 recorded.
14 range not ascertained.

Recoil	{	Horizontal, with 20 pds. charge	.	.	.	4 feet.
		Horizontal, with 25 pds. charge	.	.	.	6½ "
		At 10° and 15°, about	.	.	.	3 "
		At 35° and 39°, about	.	.	.	2 "

Diameters and Enlargements of the Bore of the 12 inch Columbiad.

ENLARGEMENT BEYOND THE ORIGINAL DIAMETER AFTER THE UNDER-MENTIONED FIRES.																REMARKS.	
Distance from muzzle.	Original diameter.	2d.	4th.	6th.	8th.	10th.	14th.	18th.	26th.	34th.	42d.	55th.	69th.	84th.	93d.		
Inches.	{	111	9.008	—	—	—	—	—	.002	.003	.003	.003	.004	.004	.005	.005	The first measurement of the chamber was made after the 14th fire. The diameters then found are stated in the second column.
		110	9.012	—	—	—	—	—	.002	.002	.003	.003	.004	.004	.005	.005	
		109	9.013	—	—	—	—	—	.001	.001	.002	.003	.003	.004	.005	.005	
		108	9.014	—	—	—	—	—	.001	.001	.002	.003	.004	.005	.005	.005	
		107	9.014	—	—	—	—	—	.001	.001	.002	.003	.004	.005	.005	.005	
		106	9.014	—	—	—	—	—	.002	.002	.002	.003	.003	.004	.005	.005	
		105	9.014	—	—	—	—	—	.001	.001	.001	.002	.003	.004	.005	.005	
		104	9.017	—	—	—	—	—	.000	.001	.001	.002	.002	.003	.004	.004	
		103	9.017	—	—	—	—	—	.000	.001	.001	.002	.002	.003	.004	.004	
		96	12.008	.011	.017	.019	.022	.024	.027	.027	.033	.038	.040	.042	.044	.048	
{	95½	12.008	.010	.018	.018	.021	.021	.034	.035	.040	.049	.051	.052	.054	.059	.070	No perceptible enlargement of the vent could be discerned by the instrument, which measured only 12 inches from the exterior; leaving 3 inches of the interior unexplored.
	95	12.008	.010	.018	.019	.019	.019	.035	.037	.038	.047	.050	.053	.055	.060	.070	
	94½	12.008	.008	.010	.011	.019	.021	.040	.045	.047	.050	.053	.056	.058	.063	.074	
	94	12.008	.005	.007	.010	.018	.020	.038	.040	.047	.051	.054	.055	.057	.060	.072	
	93	12.007	.005	.005	.009	.013	.015	.022	.022	.026	.030	.032	.034	.034	.040	.043	
	92	12.008	.001	.001	.002	.003	.005	.007	.008	.010	.010	.010	.011	.011	.012	.012	
	91	12.008	.000	.000	.000	.001	.001	.001	.001	.002	.002	.002	.002	.002	.003	.003	
	90	12.008	.000	.000	.000	.000	.000	.000	.001	.001	.001	.001	.001	.001	.001	.002	
	85	12.008	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	80	12.009	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
{	75	12.005	.000	.000	.002	.002	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	
	70	12.005	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	65	12.004	—	—	—	—	—	—	—	—	—	—	—	—	—	.000	
	60	12.003	—	—	—	—	—	—	—	—	—	—	—	—	—	.000	
	55	12.001	—	—	—	—	—	—	—	—	—	—	—	—	—	.000	
	50	12.000	—	—	—	—	—	—	—	—	—	—	—	—	—	.000	
	40	12.001	—	—	—	—	—	—	—	—	—	—	—	—	—	.000	
{	30	12.000	—	—	—	—	—	—	—	—	—	—	—	—	—	.000	
	20	12.001	—	—	—	—	—	—	—	—	—	—	—	—	—	.000	
	10	12.001	—	—	—	—	—	—	—	—	—	—	—	—	—	.000	

From the results stated in the foregoing tables, it appears that the maximum range, in ricochet fires, is about 3,300 yards = $1\frac{7}{8}$ miles; and that it is obtained with a charge of 20 pounds of powder, and shells weighing about 150 pounds.

The ranges obtained with charges of 20 pounds, are about equal to those given by charges of 25 pounds, at all elevations not exceeding 15 degrees, and with all the various shells, whether heavy or light.

The medium shells of about 150 pounds when loaded, range further than either the heavy or light shells, when fired horizontal or at low angles.

It appears, therefore, that charges of 20 pounds, and shells of 150 pounds are the most suitable for all elevations within 15° , and for all ranges within 4,000 yards, $2\frac{1}{4}$ miles.

In the long ranges, at high elevations, the ranges with charges of 25 pounds exceed those given by charges of 20 pounds; and the heavy shells range further than the medium or light ones. Hence, it appears that the charge of 25 pounds, and shells of about 170 pounds, are most suitable for extreme ranges at high elevations.

The light shells of 124 pounds and 130 pounds, are found to be inferior in all cases. They not only fall short in range, but they diverge more from the line of fire, and are sometimes crushed by impact when they strike.

The maximum range, with charges of 20 pounds is attained at the elevation of 35° ; and greater elevation diminishes the range. The maximum range with charges of 25 pounds is given at 39° elevation. There is, however, but little difference between the ranges at 35° and 39° .

The maximum range of all the fires, 5,800 yards, was given by a charge of 28 pounds, and a shell weighing 181 pounds.

During the ten first fires, the carriage was placed at the front end of the chassis. Four of these fires were horizontal, and six at an elevation of 22° . The latter caused the front traverse wheels to bend the traverse plates and sink them into the wood platform on which they rested, about $\frac{3}{4}$ of an inch. The traverse plates are of wrought iron $4\frac{1}{2}$ inches wide and $\frac{3}{4}$ thick. In all the subsequent fires, with the gun elevated, the carriage was placed further back on the chassis, so that the force of the recoil was sustained by the circular bolster in the centre of the platform.

This was found to be the proper position for the carriage, when firing at elevations.

At the 36th fire, when the carriage recoiled, by rolling back on its front wheels, it came up against the rear hurters with so much force, as to bend the centre pintle bolt. After completing the fire of that day, the carriage and chassis were removed, and the pintle was found broken at a part defective in the welding. A new pintle was supplied and secured to the bolster by a circular plate of cast iron. Plates of cast iron were also placed under the traverse circles, to prevent their being crushed with the wood. The carriage and chassis endured all the subsequent firing without yielding in any part; and all remains in complete order for service.

The design of the carriage, in all its arrangements for serving the gun, is found to be convenient and well adapted to the purpose. The elevating apparatus, which consists of a ratchet and pall combined with a screw, permits the gun to be elevated or depressed through its range of 40 degrees, with ease and celerity.

The fuzes generally succeeded, and of the few which are marked as failures, it is probable that if they could have been recovered, it would have been found that a portion of them had exploded. The cap of sheet lead, which is placed over the vent of the fuze, on the exterior of the shell, appears to be an effectual preventive to accidental or premature explosion of shells, while exposed in the batteries. The shell No. 12, through the negligence of the gunner, was fired without the lead cap having been removed; several days afterwards, the same shell was dug out of wet earth more than $2\frac{1}{2}$ miles distant from the gun, and its charge, fuze and cap, were found undisturbed, and in good order for service. The shell was used again at the 83d fire, with the same fuze and charge, with its lead cap removed, when it exploded at the proper time.

W. WADE.

SOUTH BOSTON, 28th November, 1846.

TO COLONEL GEORGE BOMFORD.

Boston, May 19, 1847.

LIEUT. COL. TALCOTT.

SIR: In answer to the inquiry of the Secretary of War, contained in your letter of the 12th inst., I would state that the particular objects which have occupied my attention of late, are the trials of six pounder cannon, to determine the effect of annealing, or slowly cooling, the iron when cast.

Three 6 pdr. guns were cast at the same time, from the same iron; in one of them the cooling was prolonged for several days, the other two were cooled in the usual manner, and one of the latter was bored out to a 12 pounder howitzer.

The two 6 pounders were fired with gradually increasing charges until they burst. The accompanying statement contains the particulars of their manufacture and proof.

The 12 pdr. howitzer has been fired with shells, in connection with a six pdr. gun, with balls. The purpose of this trial was to compare the ranges of 6 pdr. balls and 12 pdr. shells, fired with equal charges of powder, from guns of equal length and weight, in order to ascertain whether it might not be advantageous to increase the proportion of the latter for field service generally.

The average ranges, obtained in these trials with six pounder balls, and the common concentric shells, are about equal, and the eccentric shells range somewhat further; thus the shells being at least equal in range to the balls, they will be equal in most other respects, for effective field service, besides possessing the additional and important advantage of exploding within an enemy's lines.

Some further trials of different methods of casting and cooling iron guns are now necessary, and will prove highly useful; particularly, an arrangement which will prevent the rapid passage of the heat upwards from the liquid metal, and at the same time create a pressure upon the upper surface of the iron, during the time of its passing from the liquid to the solid state. It promises to improve the quality of the metal.

The instrument for testing the strength of iron, designed and constructed by Major Wade, determines with great accuracy and convenience, the capacity of any metal to resist a *transverse*, a *tensile*, and a *torsional* force.

He suggests an addition, which will adapt the instrument to the *crushing* of metals also; such an addition would be useful.

The numerous trials which have, at different times, been made with various kinds of fuzes and shells, have shown that the fuzes in paper cases with copper primers, fill all the requisite conditions of safety and certainty; and also, that the more expensive bronze cases may be dispensed with, as it is practically proved that shells may be cast with small fuze holes adapted to the paper cased fuzes, and that shells of this kind are broken with smaller charges, and burst with more destructive force, than those having large fuze holes.

The paper case fuzes for shells of all denominations, have the same form and are of the same dimensions in all respects, excepting length, which is varied to suit the thickness of the shell and time of flight; these conditions simplify the construction of fuzes and shells, as one set of instruments serves for preparing the fuzes and fuze holes for shells of all calibres, from the 12 pdr. to the 12 inch Columbiad, and the fuzes burn for any length of time from one to forty seconds.

Shells now on hand, having large fuze holes, may be fitted to receive the paper case fuzes, by filling the large orifice with a plug of hard wood. And shells thus altered, for the 10 inch Columbiads supplied to the bomb vessels recently fitted out, were found on sufficient trials, to explode with great certainty and exactness when fired with the highest charges.

No further trials have been made with the 12 inch Columbiad, since those reported in December last. About one hundred fires have been made with that gun, and the results have been so entirely satisfactory, that further proof is not deemed necessary. The gun and carriage remain in good order and may be placed in any battery for service.

The question, whether guns of this character shall be provided for service, and to what extent, seems to demand consideration. The experiments have shown that such a gun may be safely used in service, and that a range of 5,800 yards, with shells weighing 180 lbs. and charges of 28 lbs. of powder, may be obtained.

Fuzes adapted to such high velocities, in either ricochet firing or long ranges, are made to explode the shell at any assignable period with an almost unvarying certainty. And the shells are of such thickness and weight, that no vessel of war has sufficient strength to resist their power.

A gun, therefore, possessing these qualities, seems to be peculiarly fitted for Sea Coast defence, as no Naval Armament hitherto used or known, could support a contest. And, even if vessels of sufficient stability for the service of such heavy guns could be constructed, the firing at high elevations would be far less certain, in consequence of the difficulty of accurate direction, while the vessel is pitching or rolling.

The manifest superiority of heavy shells over solid shot appears so unquestionable, that I cannot forbear to recommend that each of the principal fortresses should be provided with a few of the 12 inch Columbiads, and that a large proportion of the armament of all the Sea Coast defences should consist of heavy Columbiads—8, 10, and 12 inch, according to locality and other circumstances.

Respectfully, your obedient servant,

GEO. BOMFORD,

Col. of Ordnance.

EXPERIMENT

IN COOLING IRON, IN CANNON,

RAPIDLY OR SLOWLY.

APRIL, 1847.

EXPERIMENTS

MADE TO

DETERMINE THE EFFECT PRODUCED ON THE QUALITY OF IRON IN GUNS, BY SLOW OR RAPID COOLING, OF THE CASTING.

THREE six pounder cannon were cast at the same time, from the same melting of iron. The moulds were similar, and prepared in the usual manner. That in which gun No. 1 was cast, was heated before casting, and kept heated afterwards, by a fire which surrounded it. Guns No. 2 and 3 were cast and cooled in the usual manner. A sheet iron cylinder lined with brick, enveloped the flask of No. 1, leaving a circular space between, for fuel, of about nine inches wide. Grates were placed at the bottom of this space, with an ash pit beneath for the admission of air to the fuel.

A charcoal fire was lighted an hour before casting, so that the flask and mould were nearly red hot at the time of casting the gun. The fire was continued constantly for three days, when it was permitted to subside gradually.

At the end of the fourth day, the gun and flask were withdrawn from the heating cylinder, while all parts were yet quite hot. The next day the mould was removed from the casting. The guns No. 1 and 2 were bored for 6 pdrs. in the usual form, and No. 3 was bored for a 12 pdr. howitzer, with a 6 pdr. chamber, as shown in the annexed drawing.

The 6 pdr. guns were fired with charges of gradually increasing force, as follows:—

Order of firing.	PROOF CHARGES.		Order of firing.	PROOF CHARGES.		Order of firing.	PROOF CHARGES.	
	Pounds of powder.	Number of balls.		Pounds of powder.	Number of balls.		Pounds of powder.	Number of balls.
1	2	1	10	2	10	19	2½	15
2	2	2	11	2	11	20	2½	16
3	2	3	12	2	12	21	3	14
4	2	4	13	2	13	22	3	15
5	2	5	14	2	14	23	3	16
6	2	6	15	2	15	24	3	16
7	2	7	16	2	16	25	3	16
8	2	8	17	2½	13	26	3	16
9	2	9	18	2½	14	27	3	16

The firing of both guns proceeded at the same time, in the following manner: Gun No. 1 was fired 10 times, and No. 2 was then fired the same number of times, when the bores and vents of both were measured. Then the firing of each was continued to the 16th fire, and again measured. They were fired in like manner and measured after the 20th and 24th fires. The gun No. 1 burst at the 27th fire, and No. 2 at the 25th fire. The former endured four of the maximum charges, and the latter two of them.

The greatest enlargement of the bores was found in that part where the ball joins the cartridge, and was the same, after the 20th fire, in both guns, viz: $\frac{9}{1000}$ of an inch. At the same time, the vents in each had enlarged from .20 to .25.

It appears from these results, that no material effect is produced on the quality of the iron, by these different methods of cooling the castings.

W. WADE.

SOUTH BOSTON FOUNDRY, April 16, 1847.

To COL. GEO. BOMFORD.

EXPERIMENTS

THE EFFECT OF ATMOSPHERIC PRESSURE ON THE MELTING OF IRON IN A HOLLOW CANNON

EFFECT OF ATMOSPHERIC PRESSURE

Two hollow cannons were used in the same time from the same melting of iron. The cannons were similar, except that in one of them a hollow tube was inserted in the top of the mould. In the other, the top of the mould was closed. The air contained in the space between the iron and the mould was expelled by the pressure of the iron as it melted. In the cannon with the tube, the iron melted at the bottom and flowed up the tube. In the cannon without the tube, the iron melted at the bottom and remained there. The air contained in the space between the iron and the mould was expelled by the pressure of the iron as it melted. In the cannon with the tube, the iron melted at the bottom and flowed up the tube. In the cannon without the tube, the iron melted at the bottom and remained there.

These results show that the pressure of the atmosphere is not sufficient to prevent the iron from melting. The iron melted at the bottom of the mould in both cases. The air contained in the space between the iron and the mould was expelled by the pressure of the iron as it melted. In the cannon with the tube, the iron melted at the bottom and flowed up the tube. In the cannon without the tube, the iron melted at the bottom and remained there.

EXPERIMENTS

MADE TO

DETERMINE THE EFFECT PRODUCED ON THE QUALITY OF IRON, IN GUNS, BY AN ATMOSPHERIC PRESSURE ON THE SURFACE OF THE IRON WHILE PASSING FROM THE LIQUID TO THE SOLID STATE.

Two 6 pdr. cannon were cast, at the same time, from the same melting of iron. The moulds were similar, excepting that in one of them, a hollow iron cylinder, with one end closed, was inserted in the top of the mould, in such manner as to enclose an air-tight space over the upper surface of the liquid iron. In casting the gun, the iron entered at the bottom and flowed up until it nearly filled the mould, leaving only a few inches of space between the surface of the iron and the closed top of the mould. The air contained in this space expands by the heat it receives from the liquid iron, and presses upon the latter with a force proportioned to the increased temperature of the air. In addition to the pressure thus produced, additional air was injected into the mould, after casting, by means of a force pump. A safety valve was placed in the top of the mould, to guard against injury from an excessive pressure.

These means, however, failed to produce as great a pressure as was desired; the instruments at hand not being sufficient for the purpose. The greatest pressure obtained was about four pounds per square inch; equal to a head of liquid iron of 15 inches height. The gun cast in an open mould, in the usual manner, is marked No. 3, and that cast in the closed mould is 4. They were both proved in the same manner as those tried in April last, by firing them with gradually increasing charges, as follows:—

Order of firing.	PROOF CHARGES.		Order of firing.	PROOF CHARGES.		Order of firing.	PROOF CHARGES.		
	Pounds of powder.	Number of balls.		Pounds of powder.	Number of balls.		Pounds of powder.	Number of balls.	
1	2	1	10	2	10	19	2½	15	No. 3 burst.
2	2	2	11	2	11	20	2½	16	
3	2	3	12	2	12	21	3	14	
4	2	4	13	2	13	22	3	15	
5	2	5	14	2	14	23	3	16	
6	2	6	15	2	15	24	3	16	No. 4 burst.
7	2	7	16	2	16	25	3	16	
8	2	8	17	2½	13	26	3	16	
9	2	9	18	2½	14	27	3	16	

Gun No. 3 burst at the 23d fire, being the first fire with the maximum charge. Gun No. 4 burst at the 27th fire, having endured four maximum charges, and bursting at the fifth.

The greatest enlargement of the bore of No. 3, measured after the 20th fire, was .006, and of No. 4, measured after the 25th fire, was .004. The vents of both enlarged from .20 to .26. The tests of the specimens cut from the sinking heads of the guns, were as follows

	Of No. 3.	Of No. 4.
Tensile strength per square inch	35575	32684
Specific gravity	7.3694	7.3775

All of the results exhibit an uniform, although not a very considerable difference in favor of the gun No. 4, which was cast under an atmospheric pressure.

The different circumstances under which the two castings cooled, probably had some influence on the quality of the iron. In that cast in the usual manner, the heat in the liquid iron passed off freely, in ascending currents, through the open top of the mould. In the closed mould, a body of confined air and of dry clay, enclosed in an iron case, intercepted these currents, and obstructed the escape of heat in this upward direction, and no doubt caused this casting to cool, not only more slowly, but more uniformly in all its parts.

Respectfully submitted,

W. WADE.

SOUTH BOSTON FOUNDRY, *January 17, 1848.*

To COL. G. BOMFORD.

REPORT

ON

FIRING A 32 PDR. BRONZE HOWITZER,

WITH

CONCENTRIC AND ECCENTRIC SHELLS.

BOSTON, 1848.

REPORT

REPORT WITH A 22 PPR. BROWNE HOUTNER

REPORT

REPORT WITH A 22 PPR. BROWNE HOUTNER

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REPORT

ON

SHELL FIRING WITH A 32 PDR. BRONZE HOWITZER; CONCENTRIC
AND ECCENTRIC SHELLS. BOSTON, 1848.

32 pdr. Bronze Howitzer—Shell Firing.

No. of fires.	SHELLS.				RANGE—YARDS.		ANGLE OF DIVERGENCE.	
	Thickness. Inches.	Weight. Lbs. Ozs.	Eccen- tricity. Inches.	Elevation of howitzer. Degrees.	First graze.	Total.	Left.	Right.
1	.83	19. 9	.0	0°	419	1722	2°. 0'	—
2	.84	19. 11	.0	0	398	1798	—	2°. 38'
3	.81	19. 6	.0	0	351	2130	6. 14	—
4	.82	19. 8	.0	0	376	1986	1. 48	—
5	.80	19. 8	.0	0	350	1836	2. 10	—
6	.83	19. 10	.0	0	406	2036	2. 31	—
7	.82	19. 8	.0	0	400	2009	—	0. 26
8	.83	19. 11	.0	0	356	1549	0. 30	—
9	.82	19. 9	.0	0	306	2188	1. 33	—
Mean	.82	19. 9	—	—	374	1917	—	—
10	.81	19. 6	.11	5°	—	1899	0°. 10'	—
11	.86	20. 0	.21	5	—	2517	2. 17	—
12	.85	19. 15	.24	5	—	2574	—	0°. 39'
13	.82	19. 9	.16	5	—	2129	1. 22	—
14	.84	19. 15	.22	5	—	2647	0.	0.
15	.82	19. 9	.14	5	—	2023	—	0. 37
16	.81	19. 5	.11	5	—	2101	0. 36	—
17	.84	19. 15	.19	5	—	2196	—	1. 30
18	.86	20. 1	.22	5	—	2581	0. 23	—
Mean	.84	19. 12	—	—	—	2296	—	—
19	.89	20. 0	.31	9½°	—	2988	—	1°. 47'
20	.84	19. 8	.36	9½	—	2940	—	5. 22
21	.79	19. 6	.30	9½	—	3064	—	0. 28
22	.85	20. 0	.32	9½	—	2904	0.	0.
23	.86	19. 15	.30	9½	—	2975	—	2. 29
24	.80	20. 0	.33	9½	—	3139	1°. 30'	—
25	.85	19. 13	.28	9½	—	—	—	—
26	.84	19. 13	.32	9½	—	3101	—	0. 40
27	.83	19. 7	.40	9½	—	—	—	—
Mean	.85	19. 12	—	—	—	3016	—	—

32 pdr. Bronze Howitzer—Shell Firing—Continued.

No. of fires.	SHELLS.				RANGE—YARDS.		ANGLE OF DIVERGENCE.	
	Thickness. Inches.	Weight. Lbs. Ozs.	Eccen- tricity. Inches.	Elevation of howitzer. Degrees.	First graze.	Total.	Left.	Right.
28	.70	17. 6	.0	0°	346	2262	—	0°. 4'
29	.71	17. 11	.0	0	367	2200	4°. 56'	—
30	.72	17. 9	.0	0	—	1782	0. 51	—
31	.73	17. 12	.0	0	332	2013	2. 15	—
32	.71	17. 8	.0	0	383	2266	0. 06	—
33	.73	17. 10	.0	0	323	2029	—	0. 27
34	.71	17. 10	.0	0	355	2634	2. 17	—
35	.74	17. 10	.0	0	376	Broke	—	—
36	.76	17. 10	.0	0	386	2295	1. 58	—
Mean	.72	17. 9½	—	—	359	2185	—	—
37	.74	17. 14	.22	5°	—	1804	0°. 57'	—
38	.74	17. 13	.17	5	—	Burst	—	—
39	.73	17. 12	.19	5	—	2723	—	1°. 15'
40	.73	17. 12	.18	5	—	2365	1. 30	—
41	.73	17. 13	.22	5	—	2597	0. 52	—
42	.73	17. 15	.18	5	—	—	—	—
43	.76	18. 0	.17	5	—	2388	1. 18	—
44	.73	17. 15	.12	0	—	2105	—	0. 30
45	.75	17. 14	.22	9½	—	2609	1. 20	—
Mean	.74	17. 14	—	5°	—	2375	—	—
46	.75	17. 15	.35	0°	285	—	—	—
47	.74	17. 15	.35	0	270	—	—	—
48	.75	18. 0	.35	0	298	2117	4°. 14'	—
49	.72	18. 5	.28	5	—	—	—	—
50	.74	18. 0	.34	5	—	—	—	—
51	.76	18. 2	.34	5	—	—	—	—
52	.78	18. 3	.34	9½	—	2806	3. 50	—
53	.72	18. 5	.33	9½	—	—	—	—
54	.74	18. 0	.34	9½	—	—	—	—
Mean	.745	18. 1½	—	—	284	—	—	—

32 pdr. Shell Bronze Howitzer—Shell Firing—Continued.

No of fires.	SHELLS.					RANGE—YARDS.		ANGLE OF DIVERGENCE.		
	Thick- ness. Inches.	Weight. Lbs. Ozs.	Eccen- tricity. Inches.	Position of centre of gravity.	Eleva- tion. Degrees.	First graze.	Total.	Left.	Right.	Yards.
55	.74	17. 14	.39	Right	0°	383	1650	—	8°. 45'	251
56	.76	17. 14	.45	Left	0	406	1578	5°. 25'	—	149
57	.71	17. 15	.41	Up	0	—	—	—	—	—
58	.70	17. 10	.27	Down	0	509	1434	1. 7	—	28
59	.87	20. 0	.20	Up	0°	448	1601	0°. 2'	—	1
60	.86	20. 3	.0	0	0	415	2023	3. 25	—	121
61	.85	19. 15	.23	Down	0	370	1354	0.	0.	0
62	.83	19. 5	.44	Right	5°	—	1468	—	3°. 38'	93
63	.82	19. 5	.42	Left	5	—	1283	3°. 53'	—	87
64	.88	20. 2	.0	0	5	—	1463	0. 14	—	6
65	.81	19. 7	.41	Up	5	—	2505	1. 30	—	66

The range of No. 57 was observed at one station only, and is estimated at 2200 yards.

The charge of powder used in all the fires was 3½ pounds.

The eccentricity of the shells was caused by placing the centre of the *core* beyond the centre of the exterior sphere; making the thickness of metal greatest at the fuze hole, and least on the side opposite. The centre of gravity is in the axis of the fuze hole, and, in the eccentric shells, is between the centre of the sphere and the fuze. The measures given in the columns of eccentricity, show the distance between the centres of the interior cavity and of the exterior sphere; and are equal to half the difference between the thickness of metal on opposite sides, measured on the axis of the fuze.

In noting the position of the centre of gravity, the terms *right* and *left* denote that the centre of gravity of the shell, when placed in the bore, is in the horizontal plane which passes through the axis of the bore, and to the right, or left, as stated. The terms *up* and *down*, denote that the centre of gravity of the shell is in the vertical plane, through the same axis. In both cases, the centre of gravity is placed in front of the vertical plane which passes through the centre of the shell perpendicular to the axis of the bore, and midway between that plane and the axis.

In all the fires previous to No. 55, the centre of gravity was *up*.

The fires from No. 55 to 65 were arranged with a view to compare concentric and eccentric shells, and to ascertain in what manner the flight

of shells is affected, when eccentric, by placing their centres of gravity in different positions.

The fires from 55 to 58 were four highly eccentric shells. The thinnest part at the bottom being about $\frac{1}{2}$ inch thick, and the part about the fuze being more than an inch thick. The centres of gravity were placed in the four different positions, right, left, up, and down; and the flight of the shell in each case, took a corresponding direction. The divergence right, and left, was strikingly manifested to the observers at the gun, on seeing the successive skips of the shells trace on the water curved lines, conforming in their direction to the position of their respective centres of gravity. The divergence in one case to the right, and in the other to the left, make together an angular difference of 14° —and in distance 400 yards, which is equal to one-fourth of the whole range. The result of the fires up and down, in this trial, owing to the imperfect observation of No. 57, cannot be so precisely stated; yet it was evident to the observers, that the flight of these was affected in like manner as the former. The shell No. 57, with its centre of gravity up, did not strike the water, but passed over it and fell on the land beyond; a distance of 600 yards, at least, beyond the range of shell 58, fired with its centre of gravity down.

The fires from 62 to 65 were similar to the foregoing; except, that a concentric shell was substituted for the eccentric with its centre of gravity down. The right and left fires in this trial, diverged in the same manner as in the former, but to a less extent—the angular distance being $7\frac{1}{2}^\circ$, and in distance 180 yards. The ranges of the right, left, and concentric shells were nearly equal; but the range of the eccentric, with its centre of gravity *up*, greatly surpassed the others; the proportion being as 25 to 14.

In the three fires, 59 to 61, there was one each of *up*, *down*, and concentric. The two former follow the same law as in the former trials. The range of 59, with its centre of gravity up, exceeded considerably 61, with its centre of gravity down. Neither of them deviated from the line of fire. The concentric, however, greatly surpassed both in range, and diverged considerably from the line of fire. These results are similar to those obtained in former trials, and all tend to prove that the flight of a projectile is materially affected by the position of its centre of gravity. If the centre of gravity is not in the centre of the projectile, and if, when the latter is deposited in the gun, the two centres do not coincide with the axis of the

bore, then the projectile will, in its flight, diverge from that axis; and an imaginary line drawn from the centre of the projectile through its centre of gravity, the latter being within the front hemisphere, will indicate the direction of that divergence. If this line be in the vertical plane of trajection, and above the axis of the bore, the divergence will be upward, and the range increased; and if below that axis, the divergence will be downward, and the range diminished. If the line be out of that plane on either side, right or left, the projectile will diverge in a corresponding direction.

This divergence appears to commence at the muzzle of the gun, and to continue throughout the flight, increasing as it proceeds. The numerous observations made, in many trials, at different times, and all the results tending to confirm this rule, we may now regard it as an established law; and, so regarding it, it seems proper to consider its practical application in service. The fact, that a projectile being eccentric does unquestionably cause a derangement in its flight, diverging from its line of fire, requires that all projectiles should be examined, to determine whether they are concentric or not; and if eccentric, to determine the position of the centre of gravity. In firing an eccentric projectile, it is important that its centre of gravity should be placed in its proper position within the gun—when charged. There is one position only in which it can be placed, that will give it any superiority over a concentric projectile. In all other positions the effect of the eccentricity is injurious, causing either a diminished range or a divergent flight. There is a practical difficulty in placing the projectile in any assigned position (when charging) which requires more time than would be allowed in action. Besides, all the advantage, which it is possible to obtain with the utmost exactness in these respects, consists in gaining some addition to the range; and this may be obtained, with a concentric projectile, in a more simple and effective manner, by giving a little additional elevation to the gun.

It appears, therefore, that concentric projectiles are in all cases preferable to the eccentric, and that eccentricity should be regarded as a defect, to be avoided as far as practicable.

With respect to solid balls, their centres of gravity are, generally, near the centre of the sphere; but most balls do contain a small cavity, caused by the contraction of the liquid metal, within, after the exterior surface has become solid. If this cavity be in or near the centre of the ball, its centre

of gravity is but little disturbed; and by careful management in casting, it may be formed in that position very nearly. This point is conceived to be of sufficient importance to merit attention in the inspection of balls.

With respect to shells, their centres of gravity are unavoidably disturbed by the vacant space left for the fuze. But this may be compensated for by an equivalent addition of metal, about the fuze hole in the interior; making all other parts of the shell of an uniform thickness. The additional thickness in this part is useful for another purpose; it contributes to the security and safety of the fuze.

All the shells used in these trials were charged with 2 oz. of powder, as a blowing charge only; and were supplied with short time fuzes. One of the shells burst at the explosion of the small charge, and another broke on striking the water at the first graze.

The shells were of two classes as to thickness and weight. The heaviest class weighed about 19 $\frac{1}{4}$ pounds, with a mean thickness of .84; the other kind weighed 18 pounds, and had a mean thickness .74. If it be desired to use lighter shells in the bronze howitzer, than those used in heavy cannon with high charges, a thickness of .8 may be safely adopted for the purpose. The carriage has endured 65 fires, and remains uninjured; it appears to be as perfect now in all parts, as when the firing commenced.

Respectfully submitted,

W. WADE.

BOSTON, *May* 6, 1848.

TO THE COLONEL OF ORDNANCE, WASHINGTON.

REPORT

ON THE

MANUFACTURE OF 24 PDR. IRON CANNON.

BOSTON, 1848.

REPORT

ON THE

MANUFACTURE OF 24 PDR. IRON CANNON.

Manufacture of 24 pdr. Iron Cannon at South Boston Foundry.

CASTING.		KIND OF IRON USED.				TIME IN			TESTS OF SPECIMENS.				INSPECTION.		
Date.	Foundry mark.	AMENIA FURNACE.			Total pounds.	Melting.		Fusion.	PROOF BARS.			GUN HEADS.		Register number.	Weight. Pounds.
		1st fusion.	2d fusion.	Gun fragments.		H.	M.		Transverse.	Tensile.	Density.	Tensile.	Density.		
October 2, 1847	520	6000	4000	—	10000	2.	30	6. 00	10260	34275	7.3285	27243	7.2193	1	5701
November 5, "	524	4000	6000	—	10000	3.	15	3. 45	9859	31546	7.3776	31707	7.3177	2	5784
" 22, "	528	3000	7000	—	10000	3.	30	5. 00	9122	37490	7.3449	29493	7.2947	3	5778
" 29, "	529	3500	7000	—	10500	3.	45	2. 30	9514	36107	7.4173	30467	7.3525	Not in spected	
December 1, "	530	4000	6000	—	10000	3.	30	3. 00	9820	35929	7.3560	30873	7.3007	4	5780
" 4, "	531	4100	6000	—	10100	3.	30	2. 45	10413	35486	7.4612	33623	7.3664	5	5805
" 7, "	532	4000	6000	—	10000	3.	00	2. 30	10369	37260	7.4066	27675	7.3430	Not in spected	
" 10, "	533	5000	5000	—	10000	3.	15	5. 00	10418	36434	7.3850	30947	7.3372	6	5826
" 13, "	534	5000	5600	—	10600	3.	15	5. 00	9620	35427	7.3494	31050	7.2826	7	5762
" 16, "	535	5000	7000	—	12000	3.	15	5. 00	9583	33832	7.3603	31651	7.3014	8	5805
" 18, "	536	3500	6500	—	10000	3.	30	3. 00	9789	38655	7.3471	29227	7.2826	9	5758
" 21, "	537	3500	6500	—	10000	3.	30	3. 30	11197	39521	7.3773	30695	7.3034	10	5770
" 23, "	538	3500	6500	—	10000	3.	30	3. 30	10295	38389	7.3669	30113	7.2705	11	5750
" 26, "	539	3500	6500	—	10000	3.	15	3. 00	10281	37198	7.3614	30998	7.3217	12	5790
" 28, "	540	5800	1350	2850	10000	3.	30	3. 15	10381	35250	7.3407	30593	7.2797	13	5775
" 30, "	541	6900	1600	2900	11400	3.	30	4. 30	9696	35723	7.3362	29227	7.2339	14	5750
January 1, 1848	542	5000	5000	—	10000	3.	00	3. 45	10486	34865	7.3711	29947	7.2807	15	5750
" 4, "	543	5000	5000	—	10000	3.	00	4. 30	10092	39766	7.3383	26614	7.2560	16	5750
" 6, "	544	5000	5000	—	10000	3.	30	2. 45	9289	38833	7.3584	33268	7.3096	17	5810
" 8, "	545	5250	3250	2000	10500	3.	15	4. 00	9273	37260	7.3527	31441	7.3412	18	5816
" 10, "	546	5200	1700	3500	10400	3.	15	2. 15	10291	32736	7.3291	35812	7.3219	19	5800
" 13, "	547	5000	3660	1340	10000	3.	30	2. 15	9502	38122	7.3565	32044	7.3154	20	5796
Mean	—	—	—	—	—	—	—	—	10025	36368	7.3646	30668	7.3017	—	5778
32 pdr. bronze howitzer. January 17, 1848	—	Copper. 3912	Tin. 470	—	4382	4	30	4 00	Specimen No. 1 No. 2	29067 29947	8.3383 8.4573	—	Howitzer. 8.4236	1	1883

The preceding Results arranged in the order of the Density of the Gun Head Specimens, beginning with the Lowest Density.

No. of gun.	PROOF BARS.			GUN HEADS.		Weight of gun.
	Transverse.	Tensile.	Density.	Tensile.	Density.	
1	10260	34275	7.3285	27243	7.2193	5701
14	9696	35723	7.3366	29227	7.2339	5755
16	11092	39766	7.3383	26614	7.2560	5750
11	10295	38389	7.3669	30113	7.2705	5750
13	10381	35250	7.3407	30593	7.2797	5775
Mean	10345	36680	7.3421	28758	7.2519	5746
15	10486	34865	7.3511	29947	7.2807	5750
9	9789	38655	7.3471	29227	7.2826	5758
7	9620	35427	7.3494	31050	7.2826	5762
3	9122	37490	7.3449	28493	7.2947	5778
4	9820	35929	7.3560	30873	7.3007	5780
Mean	9767	36473	7.3537	30118	7.2882	5766
8	9583	33832	7.3603	31651	7.3014	5805
10	11197	39521	7.3773	30695	7.3034	5770
17	9289	38833	7.3584	33268	7.3096	5810
20	9502	38122	7.3565	32044	7.3154	5796
2	9859	31546	7.3776	31707	7.3177	5784
Mean	9886	36371	7.3660	31873	7.3095	5793
19	10291	32736	7.3291	35812	7.3219	5800
12	10281	37198	7.3614	30998	7.3267	5790
6	10418	36434	7.3850	30947	7.3372	5826
18	9273	37260	7.3527	31441	7.3412	5816
5	10413	35486	7.4612	33623	7.3664	5805
Mean	10136	35823	7.3779	32564	7.3387	5807
MEAN OF EACH DIVISION.						
1st	10345	36680	7.3421	28758	7.2519	5746
2d	9767	36473	7.3537	30118	7.2882	5766
3d	9886	36371	7.3660	31873	7.3095	5793
4th	10136	35823	7.3779	32564	7.3387	5807
Mean of all	10033	36337	7.3599	30828	7.2971	5778

The iron used in making these cannon is a cold blast, charcoal, No. 1 foundry iron. If cast as soon as it is melted, it makes soft castings, in small moulds; but if continued a long time in fusion at a high temperature, and then cast into pigs, and again melted, it becomes much harder and stronger. This process may be extended too far. The iron may become so hard that it cannot be bored or turned without great difficulty; and its fluidity, which

is lessened as the process is extended, may be so much diminished as to cause cavities in the casting.

The second fusion iron used in casting gun No. 529, was harder than usual. In boring and turning it, numerous cavities were revealed; some of them, in the interior, were one inch and a half in diameter and one inch deep. The gun was therefore rejected by the founder.

Gun No. 532 contained cavities similar to those in gun No. 529, and was rejected in like manner. On breaking up this gun, numerous cavities were found in all parts of the reinforce, and in the rear half of the chase; but none were found in the front part of the chase, in the neck, or the muzzle. All the iron came from one melting in the same furnace; but it was withdrawn from the furnace at different times, into two separate ladles. The first withdrawn was poured into the mould through a side runner, entering at the bottom, and this filled the mould up to a point about thirty inches below the muzzle. The iron last withdrawn, was then poured from the second ladle into the top of the mould until it was filled. The iron which supplied the first ladle came from the lower part of the furnace pool, and was of lower temperature than that which supplied the second ladle; for the latter came from the upper surface of the pool, where it had been exposed to an intense flame, and had been heated to a higher degree. The lower part of the casting, formed by iron from the first ladle of lower temperature, contained all the cavities; and the upper part, supplied by iron from the second ladle at a higher temperature, was sound and free from cavities. The cavities in one part and the soundness of the other, are attributed solely to the difference of temperature at which the iron was cast in each.

Samples were taken from different parts of the broken gun, and tested. The results, together with those of the proof bar and gun head from the same casting, are here given.

				Tensile strength.	Density.
Proof bar . . .				37260	7.4066
Gun head . . .				27675	7.3430
No. 532, broken gun.	{	No. 1, Neck . . .		34035	7.3137
		No. 2, Rear of chase . . .		32415	7.3313
		No. 3, Reinforce . . .		31050	7.3313

In the summary statement which is annexed to the report of manufacture, the several guns are arranged in the order of density of their respective

gun heads. It is separated into four divisions of five guns each; and gives the mean results of each division separately. These results show the uniform relation which the density of gun heads bears to their tensile strength, and to the weight of the guns. They show also, in the proof bars, that while the density follows the same order, the tensile strength exhibits a reversed order; that while the former increases, the latter decreases.

In preparing the metal for the bronze howitzer, twelve pounds of tin were added to each hundred pounds of copper, one and three-quarter hours after the latter was melted. After the tin was added, the mixture remained in fusion, exposed to the heat of the furnace, two hours before casting.

Both proof bars were cast within the gun mould; No. 1 opposite the neck, and No. 2 beneath the breech. The tensile strength stated, is that endured before the final rupture; the samples began to stretch, and take a permanent change of form, under a strain of six-tenths of their breaking weight. The density given in the column of gun heads, is that of the entire gun when finished.

W. WADE.

SOUTH BOSTON FOUNDRY, *February 25, 1848.*

SOUTH BOSTON FOUNDRY, *March 10, 1848.*

COL. G. TALCOTT, WASHINGTON.

SIR: I have received your letter of the 4th inst., inquiring the cause of the difference in the weights of the several 24 pdr. guns recently inspected at this foundry; and in answer have to say, that it is occasioned, almost entirely, by the difference in the specific gravity of the iron used in each.

I inclose herewith a report of the manufacture of these guns, showing, in detail, all the particulars of iron used, how treated, specimens tested, &c. This was prepared from my record of proceedings, with the intention of handing it to Maj. Ripley with my inspection report; but this was accidentally omitted. After casting the first gun, the casting of the second was purposely deferred, in order that the first might be bored and turned, and the qualities of its iron be tested in all forms, with a view to correct, in future castings, any defects of form, or in the quality of the iron, which might be discovered in this. The proof bar, which was tested directly after it was cast, gave good results; but when the specimen was afterwards obtained from the sinking head of the gun and tested, its strength and density were both lower than was expected. Therefore, in making the second gun, a change in the treatment of the iron was made. A larger proportion of 2d fusion iron was used, and the melted mass was continued in fusion until the samples, dipped from the furnace from time to time, indicated a much higher degree of hardness and compactness. Specimens from this second casting were tested, in all the usual forms, before casting the third gun. The results obtained, as will be seen in the report herewith, were much superior to the former, and were quite satisfactory. It was supposed, however, that the quality of the iron might be yet further improved by extending further the process of hardening. This was attempted in the third and fourth castings. The latter was made without waiting for the former to be tested, and it will be seen by the report that the process had been carried too far, and had caused the cavities in the casting which rejected the gun. This, and the loss of the seventh casting showed that the process of hardening had been carried beyond the proper limit, and the future castings were regulated accordingly.

With respect to the weight of the guns, it will be seen that the mean

weight of all is 5778 pounds, and that the mean density of the specimens taken from the heads of these twenty guns, excluding those from the two rejected guns, is 7.2971. Taking these numbers as the standard of comparison between the density of gun head specimens, and the corresponding weight for guns of this model, supposing the latter to be identical in bulk, we have the following proportion for gun No. 520, the lightest of the whole: As 7.2971, the mean density, is to 5778 pounds, the mean weight, so is 7.2193, the density of gun head No. 520, to 5716 pounds, the weight corresponding to the density of its gun head specimen. In this case, the actual weight of the gun is 15 pounds less than the weight computed from the density of its specimen.

Taking the same proportion for the gun No. 633, the heaviest of the whole, we have, as $7.2971 : 5778 :: 7.3372 : 5810$ pounds; in this case, the actual weight is 16 pounds more than the computed weight. The actual weight of the guns in these two extreme cases, differs from that which is due to the density of their respective specimens, only 15 pounds in one case and 16 pounds in the other, which is about $\frac{1}{370}$ th part of the whole weight.

Variations of this kind, it is obvious, may be produced by one or more of various causes. In the calculation, the bulk of the mass in each gun is supposed to be exactly equal. It is hardly possible to attain such an exactness as would show no difference of bulk, in such massive bodies. Then, the small specimens taken from one part of the casting, may not be an exact representative of the other parts which compose the finished gun. Then, again, the small body used in determining the densities is only about one four thousandth part of the gun, in bulk and weight; hence it will be readily perceived how a very slight inaccuracy, in determining this density, would be magnified in its application to the whole mass.

In view of these causes of variation, the uniformity of bulk and the relation of density and weight attained in this parcel of guns, may be regarded as remarkable; and serve to show the value of close attention to the different methods of treating the iron while in fusion, with the application of the various tests devised for determining its qualities when it reaches its finished state in the gun.

The inclosed report gives the particulars of the 32 pdr. bronze howitzer. The density of the metal in this piece, it will be seen, is much less than that

stated in the *Ordnance Manual*. I do not know upon what authority the latter is founded; whether upon results obtained from bronze guns in France, or in this Country; or from the general Tables of Specific gravity. If from the former, this howitzer is much below the density which should be attained. If there were any modern bronze guns in this vicinity, I would ascertain their density for the purpose of comparison. If this 32 pdr. had the density stated in the Manual, it would weigh 62 pounds more than it now does.

Respectfully I am your obedient servant,

W. WADE.

BOSTON, *May* 9, 1848.

COLONEL G. TALCOTT.

SIR: In a former letter, I adverted to the specific gravity of the 32 pdr. bronze howitzer, as being below the density stated in the Manual. Believing the density of the metal to be an important element in determining the quality of bronze cannon, I have pursued the inquiry during the manufacture of the light 6 pdr. guns, and the 12 pdr. howitzers, recently inspected here. The inspection report, furnished to Major Baker, contains the results of such trials as were made. Some of these results suggest considerations which appear to me to demand a more careful examination than is given in the brief notice of them in the report.

The specific gravity of each gun, when finished, was separately ascertained; and the results are as follows:

					STANDARD SPECIFIC GRAVITY OF BRONZE GUN METAL = 8.7.	
					Density of Guns.	Ratio.
32 pdr. howitzer, No. 1	.	.	.	.	8.4236	.9682
12 " howitzer, No. 7	.	.	.	.	8.3796	.9632
" " No. 8	.	.	.	.	8.6709	.9966
6 " gun, No. 86	.	.	.	.	8.6571	.9951
" " No. 87	.	.	.	.	8.4045	.9660
" " No. 88	.	.	.	.	8.5559	.9834
" " No. 89	.	.	.	.	8.6846	.9982

What is most remarkable among these results, is the great difference in the density of the two 12 pdr. howitzers. They were both cast at the same melting. The metal was drawn from the furnace into a ladle, and from that poured into one of the moulds. The ladle was then replenished from the furnace, when the other mould was filled. The interval between the castings was 8 or 10 minutes. The difference in density is $3\frac{1}{2}$ per cent., or about 18 lbs. to the cubic foot. This is so great that I at first suspected some error had been committed, and to remove all doubt, I reweighed both pieces in air and in water, and obtained the same results as before. We are not aware of any difference in the composition of the metal, or of its temperature; or of any dissimilarity of the moulds, or in the manner of casting, other than the few minutes of difference in the time of casting. We did not suspect that such differences would exist in two castings made from

the same pool of metal, under circumstances so nearly equal, in all respects, as these guns were.

Specimens were taken from the gun head, and from the breech square of the 6 pdr. gun, No. 86, and tested, both for density and tenacity, and the results were as follows:

STANDARD BEING 8.7.			
	Density of specimen.	Ratio.	Tenacity per square inch.
Gun head . . .	8.3316	0.9576	22179
Breech square . . .	8.7825	1.0106	46564
Whole gun . . .	8.6571	0.9951	—

Here we have a very wide difference of density, in different parts of the same casting; the breech square exceeding the gun head, more than $5\frac{1}{4}$ per cent.; equal to about 28 lbs. the cubic foot. The difference in strength is yet more remarkable, being more than two to one. The gun head specimen broke under a strain of 22,179 pounds per square inch, and the breech square endured a strain of 46,564 lbs. per inch, and remains unbroken.

These specimens exhibit, after passing this trying ordeal, a most remarkable difference in appearance. The gun head specimen appears as if it had passively yielded to the force applied, with very little change in its form; the other is distorted in a most singular manner, indicating the pertinacity with which it struggled to resist dismemberment. The projecting flanges at its ends, by means of which it is attached to the testing instrument, yielded to compression like wire drawing, so that the pincers could no longer hold it in its grasp. As a view of these specimens, in their present condition, will give a better conception of their respective qualities than any other description can do, I forward both of them to the office for your examination.

The results obtained in testing these specimens, show the relation which exists between the density, and the strength, of bronze metal; and they prove conclusively, as far as a single example can do so, that the strength increases with the density, but in a much higher ratio. And as we cannot determine, by a direct test, the strength of finished guns, we may by means of their density, which is easily ascertained, arrive at a much better knowledge than heretofore of the quality of bronze guns. I, therefore, suggest that in all future inspections, the density of bronze guns be accurately ascertained, and recorded in the inspection report. Hereafter, when a sufficient number of trials shall have been made, a minimum density may be established.

As to the cause of the difference in the two specimens from the same casting, it has long been well known that in all bronze castings, the upper parts are more porous, unsound, and less dense, than the lower parts; and for this reason the sinking heads of bronze guns are usually made long and heavy. In this casting, the sinking head was $36\frac{1}{2}$ inches, and its weight 460 lbs. The proportion between the head and the gun, in both length and weight, is about 4 to 5. The whole height of this casting, including the cascable and breech square, was 90 inches. The breech square specimen is of course taken from the bottom of the casting, and the head specimen from a point above the middle, about $\frac{2}{5}$ ths the whole height from the bottom. To this difference in the position of the specimens, a great part of the difference in their respective qualities may be attributed. But a part of the inequality may be due to the difference in the *bulk* of the castings, in the parts from which the specimens were taken. This cause we know produces, in iron castings, a very marked difference in both density and strength; the least in bulk, other things equal, giving the highest results. Whether the same law prevails in bronze castings, we do not know.

In view of the difference of quality in the two guns cast from the same melting, arising from causes which are unknown, and the inequalities of different parts in the same gun, the cause of which is known in part only, it seems proper that some practical test should be devised for arriving at a better knowledge of the subject.

Although it is known that the height and bulk of the sinking head do influence the quality of the casting beneath it, I am not aware that any definite proportions have been established. In the case of the 6 pdr. referred to, it appears that a head of $\frac{4}{9}$ ths of the whole is not sufficient; and we may infer from this, that the head should be, at least, one-half of the whole casting, in both height and weight. By casting guns with heads of different proportions, and then comparing the density of the gun with that of the head specimen, in each case, we shall arrive at a better knowledge of the proportions which should be preserved. And, if separate bars be cast from the same ladle of metal, in different forms and bulk, in the same mould with the gun, and in other separate moulds, and specimens taken from these be tested in both density and tenacity, much useful information on other points may be thereby obtained.

The testing instrument is now arranged for determining the resistance

of metals to *tensile*, *transverse*, and *torsional* strains, but not to a *compressive* force.

As bronze guns fail soonest from the indentations, scoring, and wearing of the bore, the capacity of the metal to resist injuries of this character, it appears to me, would be best determined by a direct compressive or crushing test. To adapt the instrument to this method of testing, an alteration in the principal stirrup, and its appendages for holding the specimen, will be necessary.

If it should be judged proper to investigate the quality of bronze metal, prepared by different methods, as above suggested, I recommend the application of the compressive force, as among the most important of the tests to be applied.

Respectfully your obedient servant,

W. WADE.

REPORT

OF THE

MANUFACTURE OF 100 24 PDR. IRON HOWITZERS,

AT

ALGER'S FOUNDRY.

BOSTON, 1849.

REPORT

OF THE

MANUFACTURE OF 100 TONS OF IRON

AT ALBANY, NEW YORK

REPORT

OF THE

ALBANY FOUNDRY, ALBANY, N. Y.

MANUFACTURE OF 100 TONS OF IRON

iron foundry, and at this foundry, within a year past.
During the manufacture of these 100 tons of iron, various
been tried; also, the same kinds of iron, treated in the furnace, samples
of the iron from each casting were tested as the work proceeded; and, during
its progress, the quality of the iron has been considerably improved.
All the details of the melting of the iron, and the results in testing each
casting, are given in the annexed statement.

BOSTON, 1848.

W. H. ADE.

Genl. G. Talbot, Ordnance Dept., Washington.

REPORT

OF THE

MANUFACTURE OF 100 24 PDR. IRON HOWITZERS,
AT ALGER'S FOUNDRY.

ALGER'S FOUNDRY, BOSTON, *June 19, 1849.*

GENERAL.

I transmit herewith, a report of the manufacture of one hundred 24 pdr. iron howitzers, cast at this foundry, within a year past.

During the manufacture of these howitzers, different kinds of iron have been tried; also, the same kinds differently treated in the furnace. Samples of the iron from each casting were tested as the work proceeded; and, during its progress, the quality of the iron has been considerably improved.

All the details of the melting of the iron, and the results in testing each casting, are given in the annexed statement.

Respectfully your obedient servant,

W. WADE.

GEN'L G. TALCOTT, ORDNANCE DEP'T, WASHINGTON.

Manufacture of 24 pounder Iron Howitzers at Alger's Foundry. Boston, 1848-49.

CASTINGS.		KIND OF IRON USED					TIME IN FUSION.		TESTS OF GUN-HEAD SPECIMENS.		INSPECTION.			REMARKS.	
Date.	Foundry number.	IN REFINING FIRST FUSION IRON BY SECOND FUSION.			IN GUN CASTINGS.			At gun casting	Total, in 2d and 3d fusions.	Density.	Tenacity.	Register number.	Weight of howitzer.		Date.
		Amenia.	Copake.	Time in 2d fusion.	1st fusion.	2d fusion.	3d fusion.								
1848				H. M.				H. M. H. M.						1849	The pig iron used in these guns consisted of equal parts, from the Amenian, and Fishkill Furnace in New York. The second fusion iron used, consisted of the gun heads and surplus pigs, from previous castings.
Sept. 21	636	—	—	—	8000	2000	—	4. 30 4. 30	7.193	28607	260	1476	Mar. 31		
"	21 637	—	—	—	—	—	—	—	7.180	26880	259	1476	" 31		
"	21 638	—	—	—	—	—	—	—	7.177	27633	201	1477	" 31		
"	25 641	—	—	—	6800	3200	—	3. 30 3. 30	7.220	28784	202	1488	" 31		
"	25 642	—	—	—	—	—	—	—	7.214	29178	203	1487	" 31		
"	25 643	—	—	—	—	—	—	—	7.238	31884	204	1492	" 31		
"	27 645	—	—	—	7200	2800	—	2. 15 2. 15	7.213	31264	205	1484	" 31		
"	27 646	—	—	—	—	—	—	—	7.213	30113	206	1493	" 31		
"	27 647	—	—	—	7000	3100	—	2. 45 2. 45	7.214	30999	207	1494	" 31		
"	29 649	—	—	—	—	—	—	—	7.242	31831	208	1491	" 31		
"	29 650	—	—	—	—	—	—	—	7.242	30682	209	1489	" 31		
"	29 651	—	—	—	—	—	—	—	7.217	27675	210	1485	" 31		
Oct. 2	653	—	—	—	6900	3100	—	2. 15 2. 15	7.236	30073	211	1491	" 31		
"	2 654	—	—	—	—	—	—	—	7.223	30947	212	1489	" 31		
"	2 655	—	—	—	—	—	—	—	7.228	27188	213	1487	" 31		
"	14 659	8000	2000	4. 40	—	9000	—	(2. 30 7. 10	7.253	36164	214	1491	" 31		
"	14 660	—	—	—	—	—	—	(2. 20 7. 10	7.255	35456	215	1494	" 31		
"	14 662	—	—	—	—	—	—	(2. 40 7. 20	7.231	32308	216	1493	" 31		
"	19 665	6667	3333	5. 30	—	9200	—	(5. 00 10. 30	7.161	33511	217	1479	" 31		
"	19 666	—	—	—	—	—	—	(4. 50 10. 20	7.168	28294	218	1479	" 31		
"	19 667	—	—	—	—	—	—	(5. 10 10. 40	7.170	28658	219	1478	" 31		
"	23 673	6000	4000	4. 45	—	9400	—	(5. 45 10. 30	7.194	29532	220	1480	" 31		
"	23 674	—	—	—	—	—	—	(5. 35 10. 20	7.191	30073	221	1477	" 31		
"	23 675	—	—	—	—	—	—	(5. 55 10. 40	7.192	28559	222	1483	" 31		

[illegible]

Manufacture of 24 pdr. Iron Howitzers at Alger's Foundry. Boston, 1849—Continued.

CASTINGS.		KIND OF IRON USED				TIME IN FUSION.		TESTS OF GUN HEAD SPECIMENS.		INSPECTION.		REMARKS.	
Date.	Foundry number.	IN GUN CASTINGS.				At gun casting.		Density.	Tena-city.	Regis-ter num-ber.	Weight of how-itzer.		Date.
		Ame-nia.	Co-pake.	Time in 2d fusion.	1st fusion.	2d fusion.	3d fusion.						
1849				H. M.			H. M.					1849	
Feb.	5742	8000	2000	4. 00	—	11000	—	—	7.260	32273	258	1492	Mar. 31
"	5743				—			{ 2. 45	6. 45	33865	262	1501	May 18
"	5744				—			{ 3. 05	7. 05	34307	263	1500	" 18
"	9745	8000	2000	4. 00	—	9600	500	{ 2. 15	6. 15	33423	264	1505	" 18
"	9746				—			{ 2. 25	6. 25	32361	265	1511	" 18
"	9747				—			{ 2. 35	6. 35	33599	266	1512	" 18
"	14748	10000	—	3. 45	—	11000	Amenia Heads.	{ 2. 00	5. 45	35810	267	1498	" 18
"	14749				—		5500	{ 2. 10	5. 55	35898	268	1506	" 18
"	14750				—			{ 2. 20	6. 05	35898	269	1499	" 18
"	20751	—	—	—	—	10000	5000	{ 2. 30	6. 15	35898	270	1499	" 18
"	20752				—			{ 2. 40	6. 25	32185	271	1496	" 18
"	20753				—			{ 3. 00	6. 45	34130	272	1493	" 18
"	22754	10000	—	5. 00	—	11130	5530	{ 3. 10	8. 10	30749	273	1498	" 18
"	22755				—			{ 3. 15	8. 15	37578	274	1501	" 18
"	22756				—			{ 3. 30	8. 30	36253	275	1495	" 18
Mar.	1757	—	—	—	—	10510	5210	{ 2. 50	7. 50	37136	276	1496	" 18
"	1758				—			{ 3. 00	8. 00	37136	277	1503	" 18
"	1759				—			{ 3. 15	8. 15	36135	278	1503	" 18
"	7760				—		5820	{ 2. 50	7. 50	37578	279	1505	" 18
"	7761				—			{ 3. 00	8. 00	37552	280	1504	" 18
"	7762				—			{ 3. 10	8. 10	38639	281	1508	" 18
"	9763				—			{ 1. 15	4. 45	37490	282	1503	July 28
"	9764	5000	—	3. 30	—	10150	5150	{ 1. 20	4. 50	35869	283	1504	" 28
"	9765				—			{ 1. 30	5. 00	34592	—	—	Rejected

Three howitzers are cast at each melting, from the same furnace, and the same iron. For all the howitzers from 659 to 688, the iron was prepared by a second fusion, before melting it for casting it into the gun moulds. In order to determine more certainly how long this iron might be continued in fusion with advantage to its quality, ten specimens were taken from the furnace, at different periods of the second and third fusion of guns Nos. 686-7 and 8. The results of their tests are stated in the margin of the preceding table.

In casting the guns Nos. 698, 699 and 700, an experiment was made to determine the different values of iron, taken from different levels of the same melted pool. Four specimens were taken: the first was taken from the bottom of the pool, next the hearth; the second at $\frac{1}{3}$ the height from the bottom; the third at $\frac{2}{3}$ the height; and the fourth from the upper surface of the pool. The howitzer No. 698 was cast from the lower third part of the pool; No. 699 from the intermediate part; and No. 700 from the upper third part. The results of the tests are given in a marginal statement on the Table.

All of the foregoing howitzers, up to No. 261, were inspected March 31st, 1849.

Upon a review of the tests of all of this parcel of 100 guns, it will be seen that there has been a gradual improvement in the quality of the iron from the first to the last. Iron manufactured at the Amenia Furnace, forms a principal part of the iron used in each casting. It was supposed that it might be made harder, by mixing with it a small proportion of other iron. At the beginning, iron made at the Fishkill Furnace, was added. Of the five castings in which the Fishkill iron was used, four were made before I arrived at the foundry, and before any tests were made. The iron used in these five castings, was chiefly of first fusion. On testing them, the results did not come up to the expectations which had been entertained. Iron from the Copake Furnace was then used, instead of the Fishkill iron; and all of the iron was prepared by remelting, and no iron of first fusion was thereafter used. At a later period, the use of the Copake iron was abandoned, and the Amenia iron alone was used, and this consisted of equal parts of 2d and 3d fusion iron. The guns of this class consist, therefore, of third and fourth fusion iron in equal parts.

A trial was made in one casting, No. 783, of iron, all of which was of

third fusion; but it failed. The resulting tests were good, but the casting proved unsound, and it was too hard for boring.

The mean results of all the tests of these several classes, and of their subdivisions, arranged in portions of five or six castings each, on one line, are given in the following table.

KIND OF IRON USED.	NUMBER OF		Density.	Tenacity.
	Castings.	Guns.		
Amenia and Fishkill, equal parts; 1st fusion 5 parts, 2d fusion 2 parts	5	15	7.217	29583
Amenia 4 parts, Copake 1 part; all of 2d fusion	5	15	7.231	32000
	6	18	7.243	32024
	6	18	7.268	32893
All Amenia; equal parts of 2d and 3d fusions	6	18	7.299	36139
	7	17	7.312	37163
Mean of all	35	101	7.262	33300
Mean of each class	5	15	7.217	29583
	17	51	7.247	32306
	13	35	7.305	36651

These general results show quite satisfactorily, the advantages of the present system of inspections and proof of Ordnance, while in progress of manufacture. It will be seen that the mean density of the first fifteen guns, is 7.217, and of the last seventeen, it is 7.312; a gain equal to six pounds per cubic foot. The tenacity advanced from 29583 to 37163, a difference of 7580 pounds per square inch; which is an addition of one fourth to a good standard quality of iron.

This progress is due to the use of the testing instruments, which determine the quality of the castings, from day to day, as the work proceeds; and to the careful attention of the experienced founder, who skilfully guides the future processes, by the results of the past, avoiding such as yield inferior fruits, and securing those which maintain and improve the superior qualities.

W. WADE.

BOSTON, June 19, 1849.

TO THE COLONEL OF ORDNANCE, WASHINGTON.

REPORT

ON THE

MANUFACTURE AND THE EXTREME PROOF

OF

TWO 8 INCH COLUMBIADS;

ONE

CAST SOLID, AND COOLED FROM THE EXTERIOR,

THE OTHER

CAST HOLLOW, AND COOLED FROM THE INTERIOR.

FORT PITT IRON WORKS.

1849.

REPORT

ON THE

MANUFACTURE AND THE EXTREME PROOF

Two 8 inch Columbiads; the one of them, No. 1, was cast solid in the usual manner; the other, No. 2, was cast hollow, according to the plan proposed by Lieutenant Rodman, on a hollow core, through which a stream of water passed while the metal was cooling. The iron for both castings was melted at the same time in two furnaces, each containing 2500 lbs. of iron, and was poured into a common reservoir; the liquid iron remained in the reservoir one hour exposed to a high heat; and was then elevated by a screw apparatus into a common reservoir from the reservoir it passed to a small tank, which after passing a few feet, separated into two branches, each leading to a separate mould. The solid casting remained in an open pit, and cooled in the usual manner.

FORT PITT IRON WORKS

The hollow casting was cooled in the usual manner, by passing a stream of water through the core, for a period of forty hours, when the core was withdrawn; after which the water passed through the interior cavity formed by the core for twenty hours. The average quantity of water passed through during the whole period was 164 cubic feet per minute, or 100 feet per hour; making in all 6560 cubic feet, weighing 161 tons. The temperature of the water was increased twenty degrees during the first hour; thirteen degrees during the twentieth hour; eight degrees during the fortieth hour; and three degrees during the sixtieth and last hour. The weight of the

REPORT

OF THE

MANUFACTURE AND PROOF OF 8 INCH COLUMBIADS, CAST AT THE
FORT PITT WORKS, AUGUST 4TH, 1849, BY MESSRS. KNAP AND
TOTTEN.

Two 8 inch Columbiads were cast at the same time, from the same iron. One of them, No. 1, was cast solid in the usual manner; the other, No. 2, was cast, according to the plan invented by Lieutenant Rodman, on a hollow core, through which a stream of water passed while the metal was cooling. The iron for both castings was melted at the same time in two air furnaces, each containing 14,000 pounds of the same kinds of iron. After melting, the liquid iron remained in the furnace one hour exposed to a high heat; and was then discharged by separate streams into a common reservoir. From the reservoir it issued in a single stream, which after proceeding a few feet, separated into two branches, each leading to a separate mould. Both moulds were filled at the same time.

The solid casting remained in an open pit, and cooled in the usual manner.

The hollow casting was cooled, in the interior, by passing a stream of water through the core, for a period of forty hours, when the core was withdrawn; after which, the water passed through the interior cavity formed by the core, for twenty hours. The average quantity of water passed through during the whole period, was 1.66 cubic feet per minute, or 100 feet per hour; making in all 6000 cubic feet, weighing 187 tons. The temperature of the water was increased twenty degrees during the first hour; thirteen degrees during the twentieth hour; eight degrees during the fortieth hour; and three degrees during the sixtieth and last hour. The weight of the

water passed through, is thirty times the weight of the casting; and the heat imparted by the casting to the water, and carried off by the latter, is equal to ten degrees on the whole quantity of water used. The mould for this casting was placed in a covered pit, which had been previously heated to about four hundred degrees; and this heat was kept up as long as the stream of water was supplied.

Both Columbiads were completed and inspected September the 6th, and were found to be accurate and uniform in their dimensions and weights.

In order to lessen the labor of proving the guns, they were suspended like pendulums. For this purpose, triangular frames of rough pine timber were prepared; each piece, ten inches square and thirty feet long. One side of each frame rested on the ground, the sills of each pair being ten feet asunder; the apex of each pair of triangles inclined towards each other, being four feet asunder at the top. Each gun was suspended by four wrought iron rods attached to a rocking shaft, which rested on steel pedestals, at the apex of the triangles. The shaft is a bar of cast steel $2\frac{1}{4}$ inches square. The two rods which support the rear of the gun, are $\frac{3}{4}$ inch square; and the two, which support the front, are $\frac{5}{8}$ inch square. The former connect with breeching straps, which pass under and in rear of the gun; the latter, with a collar encircling the neck. The weight of the whole—shaft, rods and straps—is 344 pounds.

Further to facilitate the labor of proving, a butt of earth was erected to receive the balls. This consists of refuse saw-mill slabs, the lower ends of which are inserted in the ground, and the upper ends are supported by binding timbers. The butt is sixteen feet wide in front, 13 feet deep, and 8 feet high. A hole for the passage of the balls is made in the front and rear, and closed with loose brush, and the butt is filled with earth. It is placed about sixty feet in front of the suspended guns, near the base of a steep hill in its rear. The balls pass through the butt, and lodge on the hill-side beyond, or roll out.

For the protection of the gunners, a barrier similar to the butt was erected in rear of the guns, with a strong projecting cover in its rear.

Friction primers received from Fort Monroe Arsenal were used in firing. They were pulled off by a small cord which passed from the gun to the rear of the barrier.

To insure an equality in the proof of the two guns, they were fired

alternately; one discharge from each, in succession: the powder in the cartridges of each pair being of the same proof range, and taken from the same cask. The charges used in the proof were, as follows:—

Proof Charges.

1st fire, 12 pounds powder, 1 ball and 1 wad.

2d fire, 15 pounds powder, 1 shell and 1 sabot.

Service Charges.

10 pounds powder, 1 ball and 1 sabot.

Mean weight of balls used $63\frac{1}{2}$ pounds.

Mean weight of shells used 49 pounds.

The mean proof range of the powder used is 298 yards.

The firing commenced September 7th; and in order to try the suspending apparatus, the first fire was made with a service charge of powder, without a ball. Then nine full service charges were fired. The guns were then laid on the ground, and fired with the two prescribed proof charges; after which they were replaced in the suspending frame and fired with service charges, to the end. In the 84th and 85th fires of gun No. 2, a shell was substituted for the ball, for the purpose of determining the initial velocity of shells, in this class of guns.

The proof proceeded, firing each gun alternately, up to the eighty-fifth fire; at which the Columbiad No. 1, cast solid, burst. The proof then proceeded with the Columbiad No. 2, cast hollow, which burst at the two hundred and fifty-first fire; having endured nearly three times more service than the former.

Both guns split, through the breech and reinforce, in nearly equal parts, the fracture diverging in front of the trunnions, and terminating on opposite sides of the chase; leaving the latter, almost entire, in one piece. The plane of fracture in gun No. 1 is inclined to the plane of the vent, at an angle of about 62° , and in gun No. 2, the planes of fracture and of vent coincide.

On examining the fragments, both guns were found to contain interior fissures about the region of the charge, the position and extent of which are shown in the annexed sketches. (Plate V.) The appearance of these fissures indicates that they commenced at an early period of the firing, and that they had been enlarged, and worn, by the fires made after their original formation. The surfaces of the fracture, at the inside edge joining

the bore, on the upper side of gun No. 2, presented a strongly marked appearance of having been worn, or fused off, smooth, by many fires. The worn surface extended from the vent forward, beyond the centre of the ball, and about one inch in depth from the bore outward.

The surfaces of fracture, on the opposite side of the same gun, exhibited the rough sharpness usual in recent fractures. There is a cross crack on the exterior, behind the rim-base, encircling a part of the same gun, the depth of which is not ascertained.

The bores and vents were measured from time to time, and the results are given in the accompanying tables. It will be observed that the enlargements of the bore with equal numbers of fires, are greatest in the gun cast solid. The measures of the vents as stated in the table, do not give the whole enlargement; as the measuring instrument will not enter the narrow sinuous cavities which are formed in the interior. The gun which split through the vent, developed cavities which would have required a vent plug 1 inch diameter to embrace all of them.

Samples were taken from the sinking heads of the guns, and tested; and also from the fragments after bursting. The latter were taken from the part opposite the chamber, and in such manner, that their planes of fracture coincide with the axis of the bore—corresponding with the fractures made in guns when they burst. The position of the several samples is shown in the sketches—Plate V.

The results of the testing are given in the following table:—

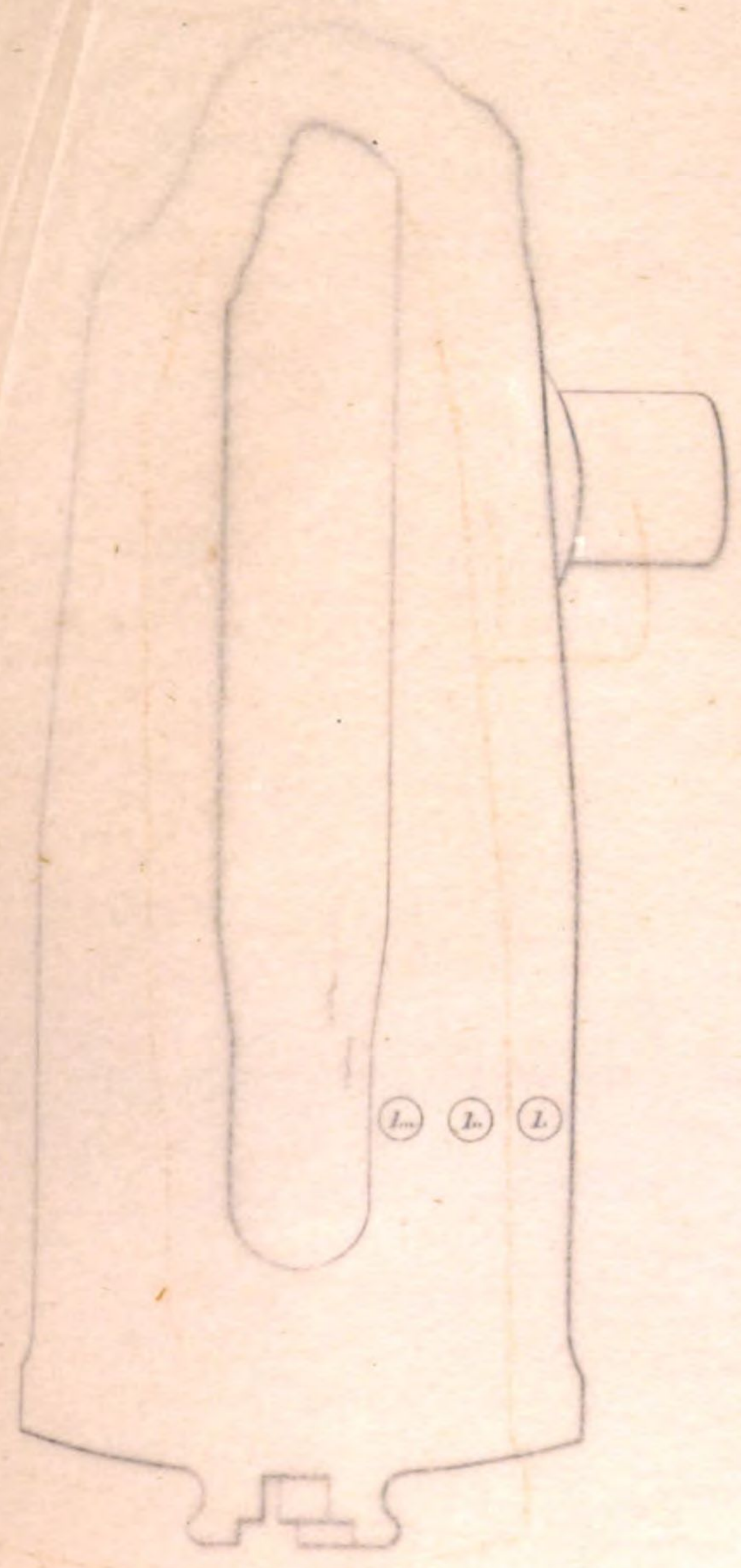
8 Inch Columbiads



No. 1



No. 2



the bore on the upper side of gun No. 2, presented a strongly marked appearance of having been worn, or forced off, smooth, by many fires. The wear appears to have been the most forward, beyond the centre of the ball, and about the same distance from the top of the bore.

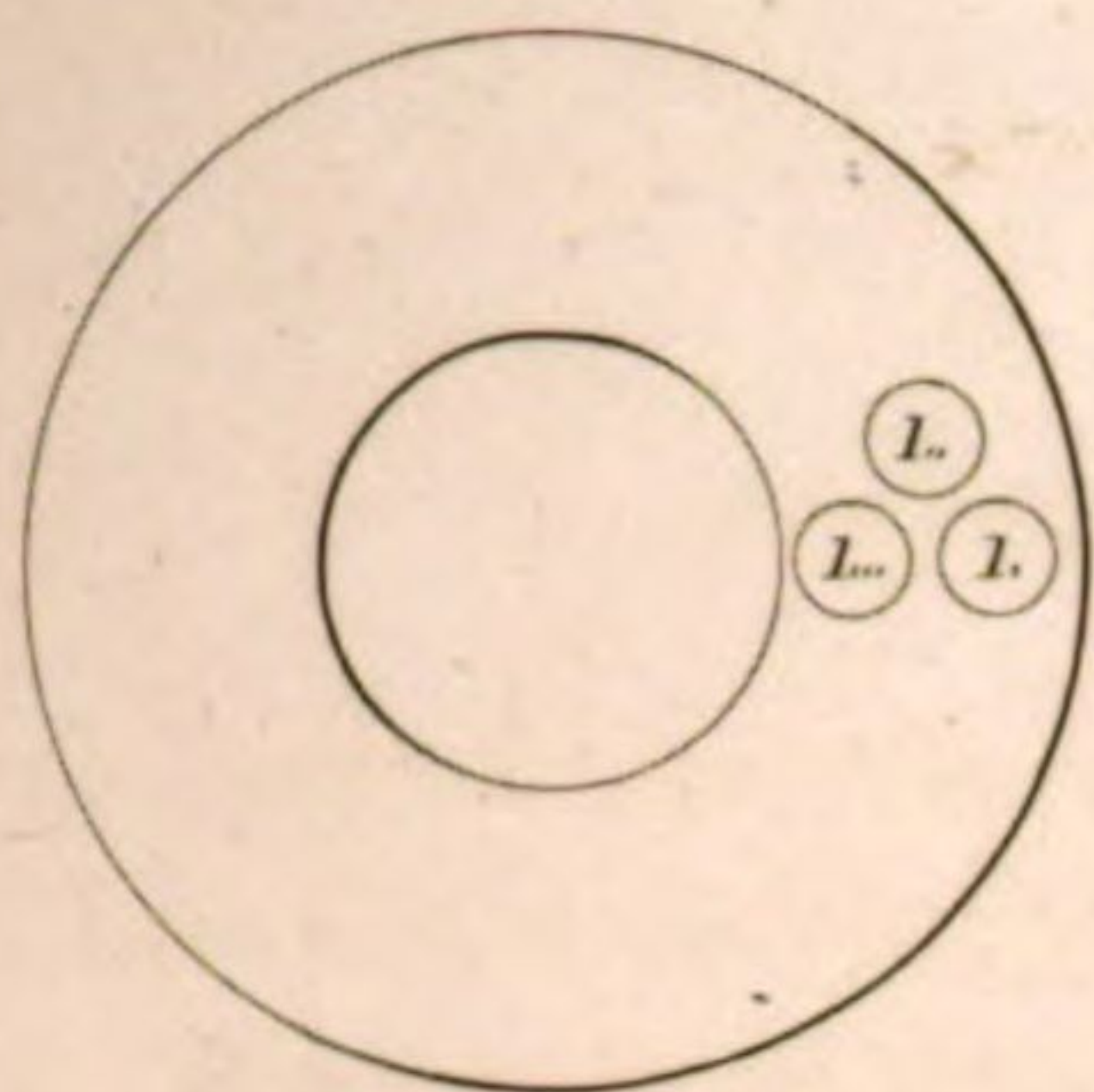
The upper side of the breech of the same gun, exhibited the same appearance, but in a more marked degree. There was a cross crack on the surface, about the middle, extending a part of the way down the depth of the breech.

The lower side of the breech of the same gun, was also tested, and the results are given in the following table. It will be observed that the enlargement of the bore with repeated charges of shot, was greatest in the gun cast with the greatest amount of shot, as stated in the table; do not give the whole enlargement, as the measuring instrument will not enter the narrow annular cavities which are formed in the interior. The gun which split through the vent, developed cavities which would have required a vent plug 1 inch diameter to embrace all of them.

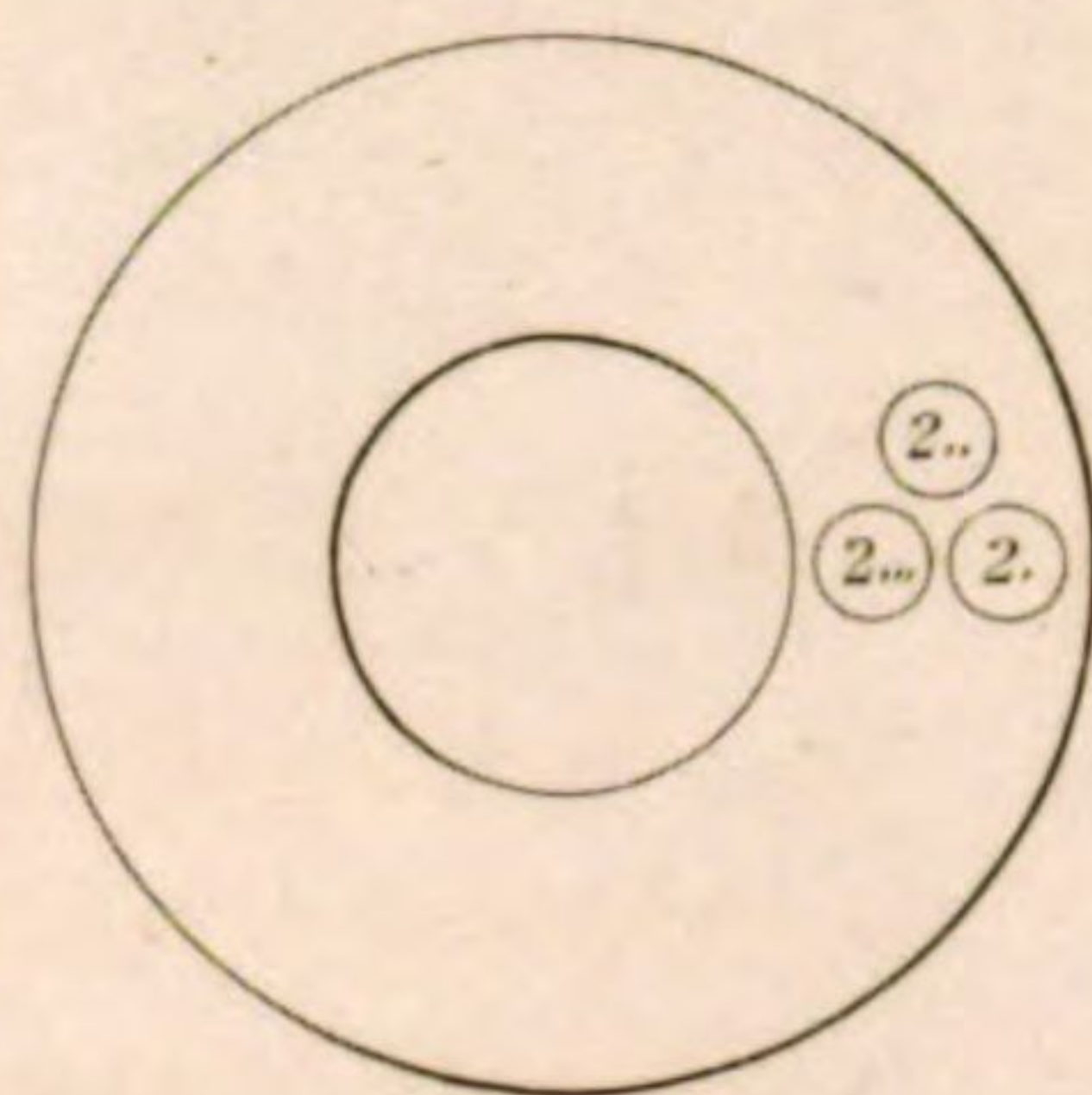
Samples were taken from the sinking heads of the guns, and tested; and also from the fragments after bursting. The latter were taken from the part opposite the chamber, and in such manner, that their planes of fracture coincide with the axis of the bore—corresponding with the fractures made in guns when they burst. The position of the several samples is shown in the sketches—Plate V.

The results of the testing are given in the following table:—

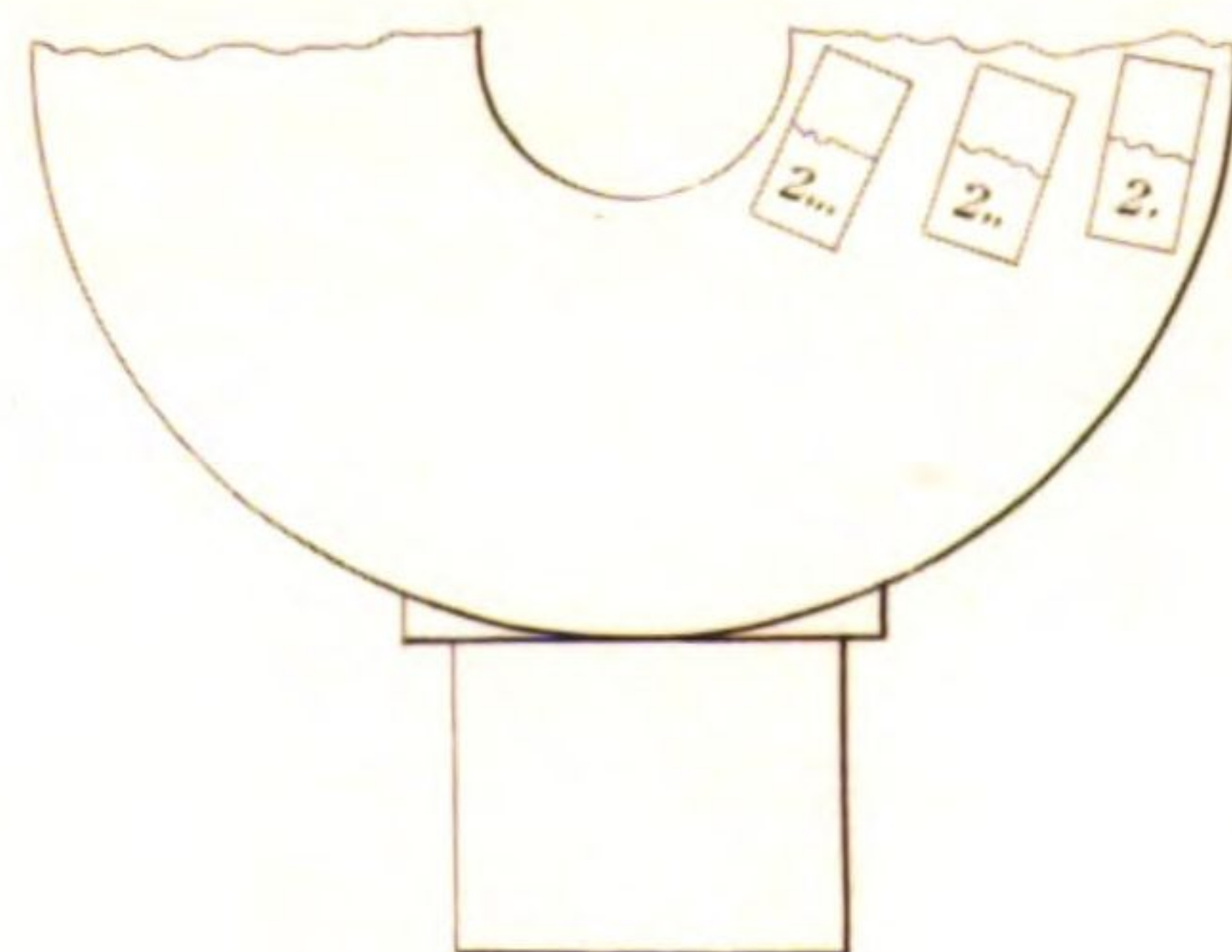
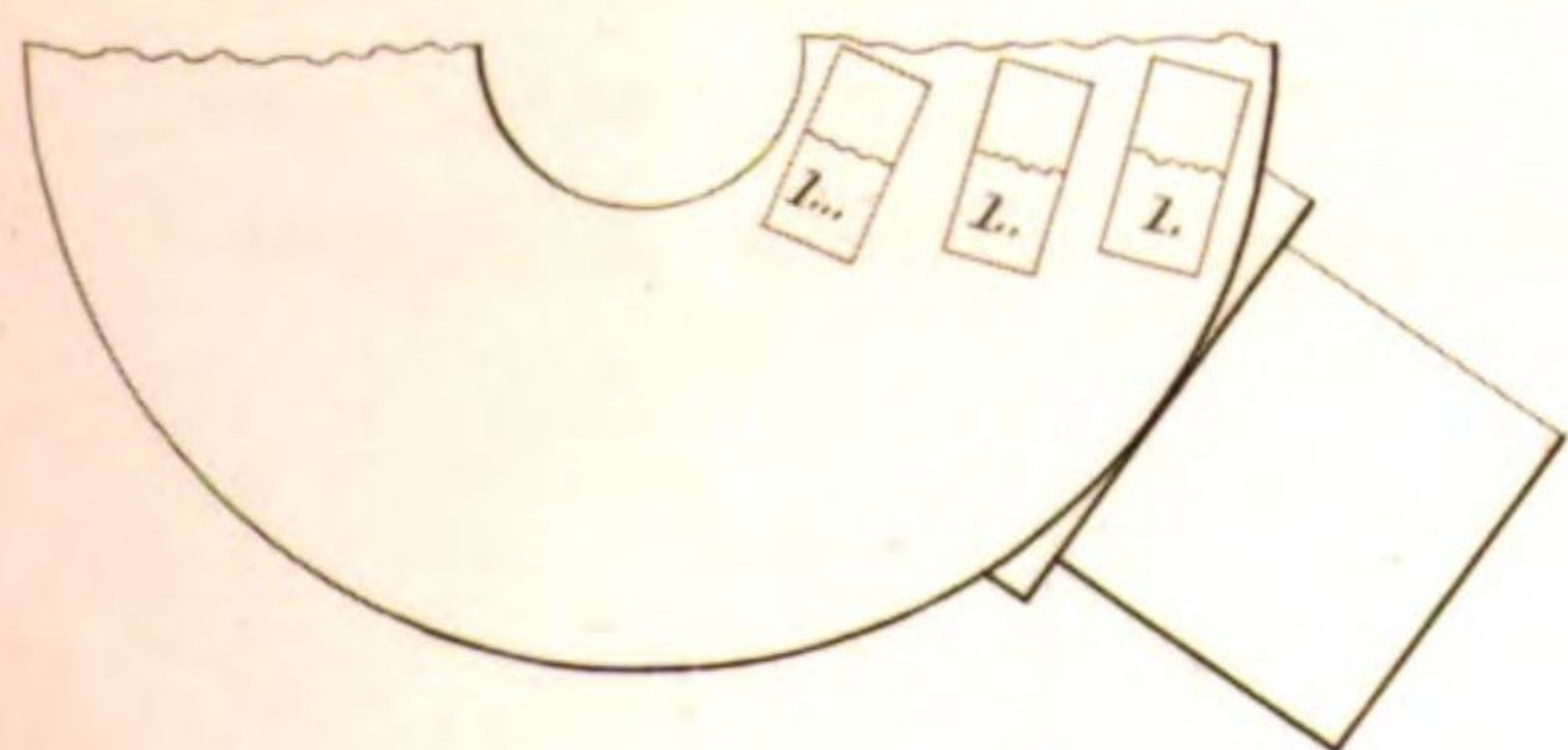
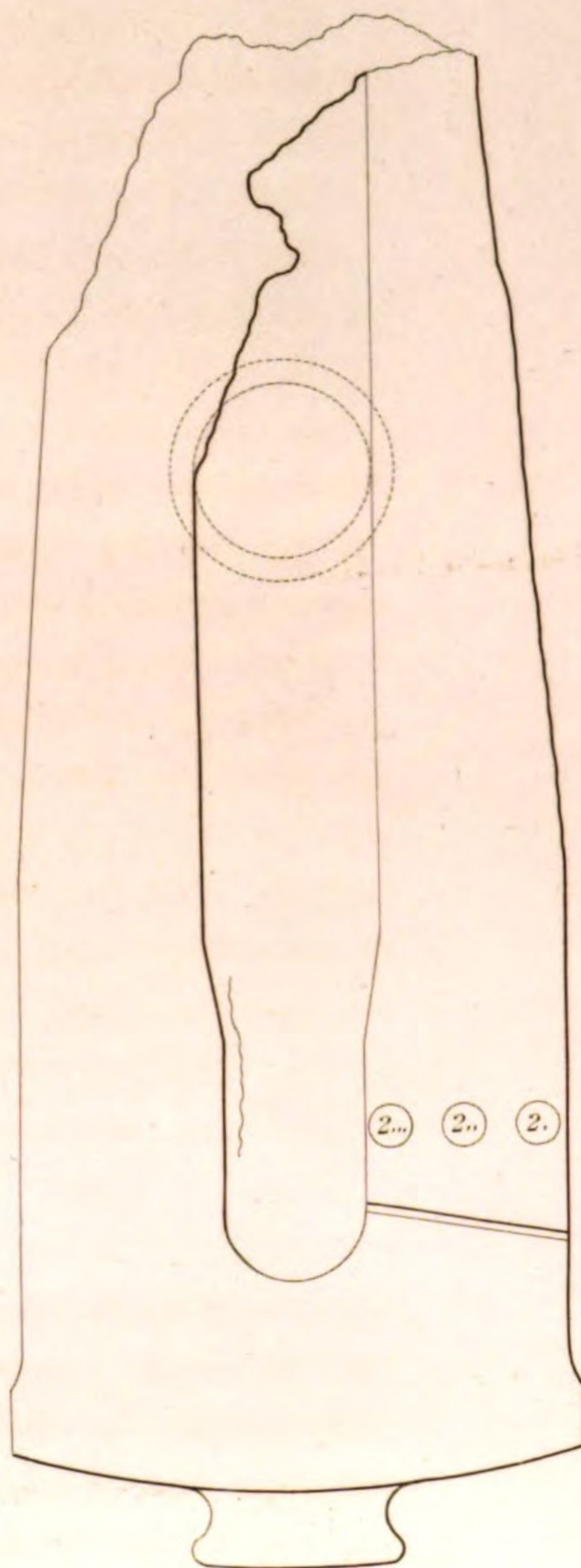
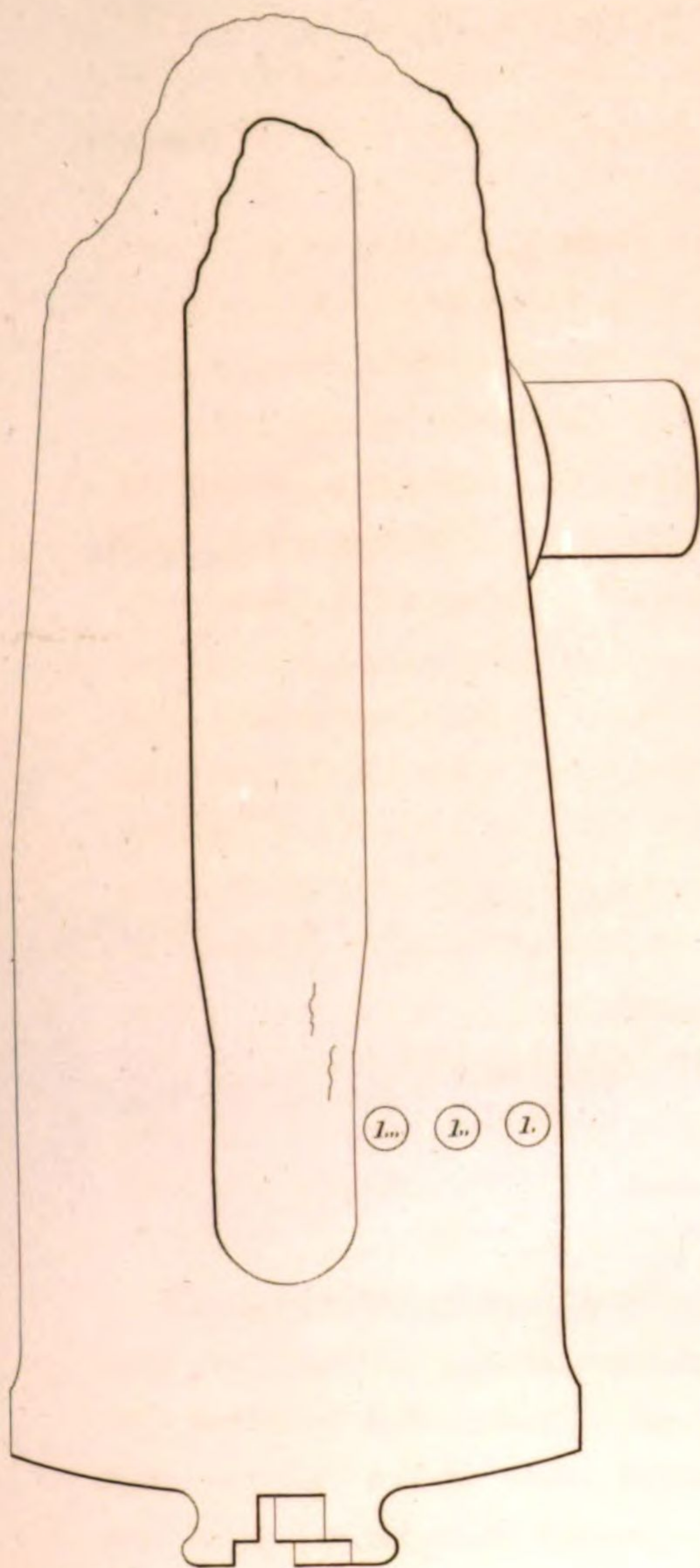
8. Inch Columbiads.



N^o 1.



N^o 2.



Scale $\frac{1}{12}$.

Tests of Samples.

Position of samples, and distance from centre of the gun.		Mark.	Density.	Tenacity.	
Gun heads	{ Gun No. 1, cast solid . }	Inches.			
		7.25	1—H.	7.236	27780
		6.20	1—H..	7.226	28716
		5.15	1—H...	7.205	26212
		Mean	7.222	27569	
	{ Gun No. 2, cast hollow . }	7.25	2—H.	7.235	28401
		6.20	2—H..	7.235	26949
		5.15	2—H...	7.228	27243
		Mean	7.233	27531	
	Fragments	{ Gun No. 1 . . . }	11.25	1—I	7.218
7.8			1—II	7.213	27188
4.5			1—III	7.228	25889
Mean			7.220	26459	
{ Gun No. 2 . . . }		11.25	2—I	7.213	29481
		7.8	2—II	7.234	28384
		4.5	2—III	7.211	27317
		Mean	7.219	28394	
RECAPITULATION.					
Gun No. 1, cast solid		{ Gun head	—	7.222	27569
	{ Fragment	—	7.220	26459	
	Mean	—	7.221	27014	
Gun No. 2, cast hollow	{ Gun head	—	7.233	27531	
	{ Fragment	—	7.219	28394	
	Mean	—	7.226	27962	

There is nothing worthy of special note in these results, other than that they are generally of a low order, especially in their density. There are no very material differences in the samples taken from different parts of the same casting, nor in those taken from similar parts of different castings, excepting the fragment samples of the two guns. In these, the tenacity is considerably lower in No. 1, and higher in No. 2, than the general mean. This difference, although not of large amount, and the difference of indentations and enlargements of the bores by firing, are both in favor of the gun cast hollow, but they are not sufficient to account satisfactorily for the strongly marked difference in the endurance of the two guns.

No other cause for this unequal endurance can be perceived, but that of the different methods by which the castings were cooled. The precautions taken, to insure an equality of the material composing the two guns, and to preserve an exact uniformity in their respective proofs, were such, that the different endurance cannot be ascribed to inequalities in either of these respects. Neither of the guns, however, endured a sufficient number of fires to be satisfactory. Another kind, and a better quality of iron may be used in making the 10 inch Columbiads, the proof of which may furnish more satisfactory materials for arriving at a just conclusion.

The apparatus for suspending the guns, and the butt for intercepting the balls, were found to answer well the purposes for which they were designed. The balls were generally found, after passing through the butt, exposed on the surface of the ground; and were recovered without digging. The pendulum rendered the loading and firing so convenient that twenty-five fires per hour were made.

Respectfully submitted,

W. WADE.

FORT PITT FOUNDRY, *Pittsburg*, October 26, 1849.

Diameters of Vents.

From the exterior. Inches.	GUN NO. 1.		GUN NO. 2.							
	Original.	After the 75th fire.	Original.	AFTER THE UNDER-MENTIONED FIRES.						
				75th.	100th.	125th.	150th.	175th.	200th.	225th.
1	.198	.200	.198	.200	.200	.200	.220	.220	.234	.242
2	.198	.200	.198	.200	.200	.204	.210	.210	.222	.240
3	.198	.200	.198	.198	.200	.204	.220	.224	.240	.248
4	.196	.204	.196	.198	.202	.208	.220	.220	.250	.262
5	.196	.200	.196	.198	.200	.210	.220	.226	.242	.248
6	.196	.200	.196	.199	.200	.218	.228	.240	.252	.276
7	.195	.202	.195	.199	.204	.234	.252	.262	.270	.282
8	.194	.202	.194	.200	.204	.224	.226	.230	.234	.310
9	.194	.200	.194	.200	.214	.214	.216	.220	.224	.280
9½	.194	.202	.194	.204	.204	.228	.228	.240	.248	.280

Gun No. 1, Cast Solid. Diameter and Enlargement of Bore.

From muzzle. Inches.	Original diameter.	ENLARGEMENT AFTER UNDER-MENTIONED FIRES.				
		10th.	12th.	37th.	50th.	75th.
10	8.008	.000	.000	.000	.000	.000
20	8.008	.000	.000	.000	.001	.001
30	8.008	.000	.000	.000	.001	.002
40	8.009	.000	.000	.000	.001	.001
50	8.010	.000	.000	.000	.001	.001
60	8.011	.000	.000	.000	.001	.001
70	8.011	.000	.000	.000	.001	.002
80	8.012	.000	.000	.001	.001	.003
84	8.012	.000	.000	.001	.001	.002
85	8.012	.000	.000	.001	.001	.002
86	8.012	.000	.001	.001	.002	.002
87	8.012	.001	.001	.002	.002	.002
88	8.012	.001	.002	.003	.003	.003
89	8.010	.001	.003	.004	.004	.005
90	8.010	.001	.004	.005	.006	.007
91	8.010	.002	.007	.008	.010	.013
92	8.010	.003	.016	.020	.021	.023
92½	8.010	.005	.023	.026	.026	.027
92½	8.010	.005	.026	.027	.027	.028
92¾	8.010	.006	.028	.028	.028	.028
93	8.010	.007	.029	.030	.030	.030
93½	8.010	.010	.031	.031	.031	.031
93½	8.012	.010	.032	.033	.033	.033
93¾	8.011	.011	.031	.031	.031	.035
94	8.010	.010	.027	.028	.029	.033
94½	8.010	.005	.023	.026	.029	.030
94½	8.010	.004	.023	.025	.027	.032
94¾	8.009	.006	.021	.024	.024	.031
100½	6.411	—	.005	.010	.010	.014
104	6.412	—	.003	.006	.007	.010
107½	6.418	—	.003	.005	.005	.008

Gun No. 2, Cast Hollow. Diameter and Enlargement of Bore.

From muzzle. Inches.	Original diameter.	ENLARGEMENT AFTER UNDER-MENTIONED FIRES.											
		10th.	12th.	37th.	50th.	75th.	100th.	125th.	150th.	175th.	200th.	225th.	250th.
10	8.008	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
20	8.008	.000	.000	.000	.000	.000	.000	.000	.001	.001	.001	.001	.001
30	8.008	.000	.000	.000	.000	.000	.001	.001	.001	.001	.002	.002	.002
40	8.008	.000	.000	.000	.000	.000	.001	.001	.001	.001	.002	.002	.002
50	8.008	.000	.000	.000	.000	.000	.001	.001	.002	.002	.002	.002	.002
60	8.008	.000	.000	.000	.000	.000	.001	.002	.002	.002	.002	.002	.002
70	8.008	.000	.000	.000	.000	.000	.002	.002	.002	.002	.002	.002	.002
80	8.008	.000	.000	.000	.000	.000	.002	.002	.002	.002	.002	.002	.002
84	8.008	.000	.001	.001	.002	.002	.002	.002	.003	.003	.003	.003	.003
85	8.008	.001	.001	.001	.002	.002	.003	.003	.005	.005	.005	.005	.005
86	8.009	.000	.000	.003	.003	.003	.003	.003	.004	.004	.004	.004	.004
87	8.009	.000	.001	.001	.001	.002	.002	.003	.003	.004	.004	.004	.004
88	8.009	.000	.001	.001	.001	.002	.002	.002	.003	.004	.004	.004	.004
89	8.009	.000	.000	.001	.001	.002	.002	.002	.004	.005	.005	.005	.005
90	8.010	.000	.000	.003	.003	.004	.004	.005	.006	.007	.007	.007	.007
91	8.010	.001	.002	.007	.007	.008	.008	.010	.010	.013	.013	.013	.013
92	8.010	.001	.003	.010	.010	.010	.010	.012	.018	.018	.018	.018	.018
92½	8.010	.001	.004	.013	.013	.013	.013	.013	.018	.018	.018	.018	.018
92½	8.010	.001	.005	.013	.013	.013	.013	.013	.018	.018	.018	.018	.018
92¾	8.011	.003	.007	.014	.014	.014	.014	.014	.018	.018	.018	.018	.022
93	8.011	.003	.009	.014	.014	.014	.014	.015	.018	.018	.018	.019	.027
93½	8.011	.003	.008	.015	.015	.015	.015	.016	.019	.019	.020	.032	.037
93½	8.013	.000	.006	.016	.016	.016	.016	.020	.020	.020	.020	.028	.042
93¾	8.013	.000	.006	.018	.018	.020	.020	.025	.025	.025	.027	.036	.048
94	8.014	.002	.006	.018	.018	.018	.026	.031	.031	.034	.035	.041	.053
94½	8.014	.003	.006	.018	.018	.019	.027	.035	.036	.036	.036	.047	.056
94½	8.013	.007	.010	.018	.018	.020	.026	.028	.035	.037	.037	.053	.053
94¾	8.017	.005	.017	.022	.023	.023	.023	.023	.023	.023	.029	.033	.042
100½	6.410	—	.003	.004	.005	.006	.007	—	.008	.008	—	.008	.012
104	6.411	—	.001	.002	.003	.004	.005	—	.005	.005	—	.006	.008
107½	6.412	—	.001	.002	.003	.003	.003	—	.004	.004	—	.004	.006

ON THE

MANUFACTURE OF 32 PDR. IRON CANNON.

WEST POINT FOUNDRY.

1850.

REPORT

OF THE

MANUFACTURE OF 32 LB. IRON CANNON.

WEST POINT FOUNDRY.

1850.

REPORT.

REPORT

ON THE

MANUFACTURE OF 32 PDR. IRON CANNON.

Manufacture of Iron 32 pdr. Cannon at West Point Foundry.

CASTINGS.		KINDS OF IRON USED.						TESTS OF SAMPLES.				INSPECTION.		
Date. 1850.	Foundry number.	FIRST FUSION. CWT.			SECOND FUSION. CWT.		Total. Cwt.	Time in fusion. H. M.	PROOF BARS.		GUN HEADS.		Register number.	Weight. Pounds.
		Greenwood.			Gun heads.	Stock- bridge.			Density.	Tenacity.	Density.	Tenacity.		
		No. 1.	No. 2.	No. 3.										
March 15	362	25	30	31	—	—	92	3. 10	7.322	25934	7.246	32999	20	7275
" 16	363	24	30	32	—	—	92	3. 15	7.307	28026	7.229	31261	21	7217
" 18	364	23	30	33	—	—	92	3. 35	7.281	32396	7.239	30286	22	7212
" 19	365	20	30	36	—	—	92	3. 30	7.289	30211	7.245	30276	23	7242
" 20	366	21	30	35	—	—	92	3. 30	7.288	30889	7.249	31970	24	7262
" 21	367	20	30	24	12	6	92	3. 35	7.344	26369	7.266	28990	25	7354
" 22	368	20	30	24	12	6	92	3. 15	7.313	27198	7.251	29668	26	7237
" 23	369	19	30	25	12	6	92	3. 45	7.311	31944	7.245	30012	27	7262
" 25	370	19	30	25	12	6	92	3. 20	7.293	29834	7.246	29098	28	7265
" 26	371	19	30	25	12	6	92	3. 25	7.311	33150	7.251	29567	29	7259
" 27	372	19	30	25	12	6	92	3. 30	7.314	32596	7.256	32810	30	7320
" 28	373	19	30	25	12	6	92	3. 20	7.334	29775	7.271	34722	31	7317
" 29	374	20	30	24	12	6	92	3. 15	7.336	31643	7.257	32461	32	7320
April 2	375	—	37	12	—	43	92	2. 30	7.350	27290	7.286	35261	33	7340
" 5	376	25	15	37	15	—	92	3. 00	7.345	28704	7.251	33124	34	7255
" 6	377	25	30	12	19	6	92	2. 45	7.321	32446	7.244	33918	35	7306
" 8	378	30	10	32	20	—	92	3. 25	7.318	26036	7.247	31691	36	7295
" 9	379	28	29	12	17	6	92	3. 20	7.325	26573	7.251	32309	37	7358
" 10	380	30	6	30	26	—	92	3. 10	7.335	28252	7.244	32407	38	7262
" 11	381	28	30	12	16	6	92	3. 20	7.329	27499	7.246	31619	39	7229
" 12	382	26	31	14	15	6	92	3. 30	7.352	26369	7.270	30260	40	7329
" 13	383	26	31	15	14	6	92	3. 15	7.357	27122	7.277	31177	41	7267
" 15	384	30	18	14	30	—	92	3. 20	7.344	27408	7.270	35466	42	7292
" 16	385	—	2	—	—	—	93	3. 20	7.354	27028	7.266	36728	43	7289
" 17	386	26	21	23	19	3	92	3. 15	7.327	26450	7.258	32509	44	7283

The iron used in these guns, is made at the Greenwood Furnace for this purpose expressly. Its general character is that of good *foundry* iron, of the different grades of Numbers 1, 2 and 3. These, with a small portion of gun heads, or other second fusion iron, are usually mixed in such proportions as will yield the proper degree of hardness.

Some experiments were made, in order to ascertain whether sufficient hardness with increased strength could not be obtained by omitting the No. 3, or hard pigs, and by substituting for them the softer grades of Nos. 1 and 2, prepared by remelting.

In casting gun 375, nearly half of the iron used consisted of such remelted iron, and the remainder, of first fusion Nos. 2 and 3. After testing samples from this gun, another trial was made in casting gun No. 385. In this, all of the iron used, excepting a small fraction, consisted of second fusion iron, prepared by remelting Nos. 1 and 2 pigs; the No. 3 being entirely excluded. The following are the results obtained:—

Gun heads.	Density	Tenacity.
No. 375, half 2d fusion	7.286	35261
“ 385, all 2d fusion	7.266	36728
Mean of these two guns	7.276	35994
Mean of the other 23 guns	7.252	31678

These trials having resulted so satisfactorily, the experiments will be continued in the casting of the five guns yet remaining to be cast.

W. WADE.

WEST POINT FOUNDRY, *August 21, 1850.*

REPORT
ON THE
MANUFACTURE AND THE EXTREME PROOF
OF
TWO 8 INCH COLUMBIADS
AND OF
TWO 10 INCH COLUMBIADS;
ONE OF EACH CAST SOLID, AND THE OTHER CAST HOLLOW.
FORT PITT IRON WORKS.

1851.

REPORT

MANUFACTURE AND THE EXTREME PROOF

TWO 8 INCH COLUMNS

TWO 10 INCH COLUMNS

ONE OF EACH CAST SOLID AND THE OTHER CAST HOLLOW

FORT PITT IRON WORKS

WASHINGTON, *January 24, 1852.*

COLONEL:

I submit herewith a report of the manufacture and the extreme proof of two 8 inch and two 10 inch Columbiads, cast at Fort Pitt Iron Works.

As the subject is one of much importance, I have judged it to be proper, at the risk of tediousness, to relate in minute detail all the proceedings, in both the manufacture and the proof of these guns, in order that others may possess the means of making their own deductions from the results developed, and also, to assist those who may hereafter be engaged in conducting similar experiments.

As the progress of inquiry in experiments of this character may be greatly assisted by the knowledge and opinions of intelligent practical founders, I suggest, that copies of the report be furnished to those, who from long experience in casting cannon, may be able and willing to impart useful information upon the subject.

Respectfully, I am your obedient servant,

W. WADE

COL. H. K. CRAIG, COLONEL OF ORDNANCE.

REPORT

ON THE

MANUFACTURE AND PROOF OF 8 INCH AND 10 INCH COLUMBIADS,
CAST AT FORT PITT IRON WORKS, BY MESSRS. KNAP AND CO.
1851.

Two 8 inch Columbiads were cast July 30th, 1851. The iron used was made at Greenwood Furnace, New York, and was of the following qualities, viz: $\frac{3.6}{100}$ of No. 1; $\frac{2.5}{100}$ of No. 2; and $\frac{3.9}{100}$ of No. 3: 28,000 pounds were melted in two furnaces (12,500 in one, and 15,500 in the other), about three-fourths of which was of 2d fusion, and one-fourth of 3d fusion. The Columbiads therefore consist of about three parts of 3d fusion, and one part 4th fusion.

After melting, the liquid iron remained in the furnaces two and a half hours exposed to a high heat, and was then discharged by separate streams into a common reservoir, at the same time. It was withdrawn from the reservoir in a single stream, which after proceeding a few feet separated into two branches, each leading to a separate mould, filling both moulds at the same time.

Both of the moulds were placed in open pits: one of the castings was made solid, and cooled, in the usual manner, without heating or covering the pit; the other was cast hollow, by means of a core formed on a tube of cast iron, through which, a stream of water constantly circulates while the iron is cooling. The core tube is water-tight, and is closed at the lower end. The water is conducted to the bottom of the core through an interior tube placed in the centre of the core, and open at its lower end. It ascends through the annular space between the two tubes, and is discharged from the core at a point above the casting, and flows off in a heated state.

A fire was kindled in the bottom of the pit, directly after casting, and was continued sixty hours. The pit was covered, and the iron case containing the gun mould was kept at as high a temperature as it would safely bear, being nearly to a red heat, all the time.

The water passed through the core at the rate of $2\frac{1}{2}$ cubic feet per minute, or 150 feet per hour. At twenty five hours after casting, the core was withdrawn; and the water thereafter circulated through the interior cavity formed by the core, at the same rate for forty hours; making 65 hours in all. The whole quantity of water passed through the casting is nearly 10,000 cubic feet, weighing about 300 tons, or about fifty times the weight of the casting. The heat imparted by the casting to the water, and carried off by the latter, is equal to 6° on the whole quantity of water used.

Two 10 inch columbiads were cast August 21st. Greenwood iron, of the same qualities as melted for the 8 inch guns, was used. About $\frac{1}{9}$ consisted of 1st fusion; $\frac{5}{9}$ of 2d fusion; and $\frac{1}{3}$ of 3d fusion. It was melted in three furnaces, containing 12,000, 15,000, and 19,000—in all 46,000 pounds. The liquid iron remained in fusion $2\frac{1}{4}$ hours, and was discharged from all the furnaces, at the same time, into a common reservoir, from which it issued in a single stream, and was conducted to the bottom of the gun pit, where it branched off, and entered the lower ends of both moulds at the same time.

Both moulds were placed in the same pit. One of the guns was cast solid; the other was cast on a hollow core, and cooled within, by a stream of water circulating through it, as before described. All of the space within the pit, outside of the moulds, was filled with moulding sand, and rammed. This was done, because the iron cases of the moulds were not large enough to admit the usual thickness of clay, in the walls of the mould. It was apprehended that the heat of the great mass of iron within, would penetrate through the thin mould, and heat the iron cases so much as to cause them to yield and let the iron run out of the mould. Consequently, the exterior of the mould of the 10 inch hollow gun, instead of being exposed to heated air while cooling, as was the case in the 8 inch hollow gun, was surrounded by green sand, which caused a more rapid cooling of the exterior surface of the casting.

Water was passed through the core at the rate of about 4 cubic feet per minute, or 240 feet per hour, for 94 hours; amounting in all to 22,560 feet, weighing about 700 tons, or seventy times the weight of the casting.

The mean elevation of temperature of all the water passed through the core, in 94 hours, was about $3\frac{1}{2}^{\circ}$. At the end of this period, an attempt was made to withdraw the core from the casting, which proved unsuccessful. The contraction of the iron, around it, held it so firmly, that the upper part of it broke off, leaving the remainder imbedded in the casting. The stream of water was then diminished to about two feet per minute, which continued to circulate through the core, for 48 hours. The supply of water, allotted to and circulated through both the 8 inch and 10 inch guns, was equal, in weight, to the weight of each casting, in about one hour and twenty minutes.

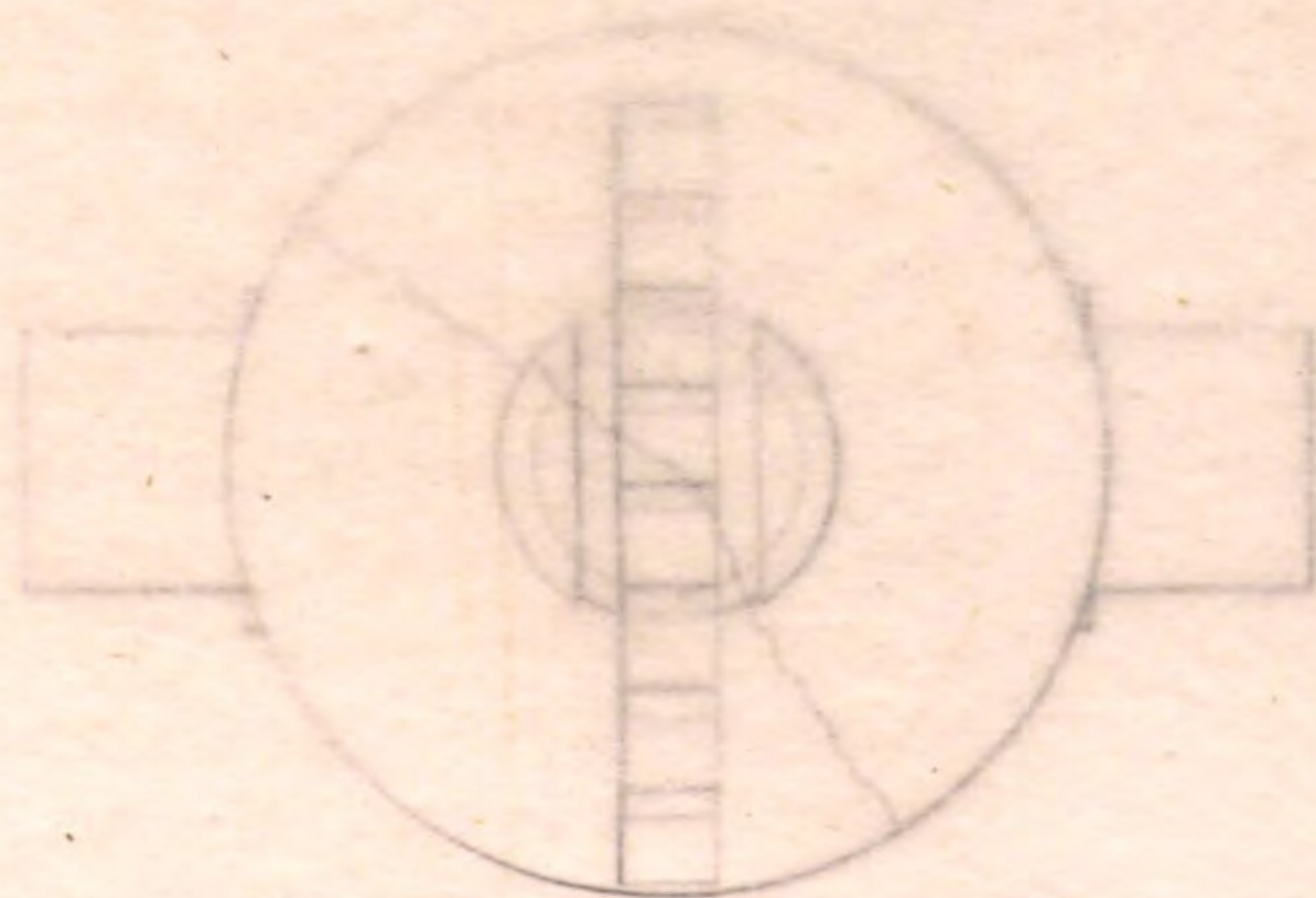
The 8 inch Columbiads were completed, and the proof of them commenced August 28th, and continued until October 2d. The proof of the 10 inch Columbiads was commenced October 7th and ended October 18th.

For convenience in loading and firing, the Columbiads were suspended by iron rods, from triangular frames made of rough pine timber. Each piece of timber is 10 inches square and 30 feet long. One side of each triangle rests on the ground, the sills of each pair of triangles being 10 feet asunder, and their apexes 4 feet; each side of the pair leaning towards the centre 3 feet. A vibrating shaft, made of cast steel $2\frac{1}{4}$ inches square, supported by steel plates, is placed at the apex of the triangles. The suspending rods are attached to the vibrating shaft above, and below, to a collar encircling the neck of the guns, and to straps which pass under and behind the breech. The two front rods for the 8 inch guns are $\frac{5}{8}$ inch square, and for the 10 inch, they are $\frac{3}{4}$ inch. The rods supporting the rear of the 8 inch gun are each $\frac{3}{4}$ inch square, and for the 10 inch, they are 1 inch square. The weight of all—shaft, rods, and straps—is for the 8 inch gun 344 pounds, and for the 10 inch, 505 pounds.

The vertical distance between the axes of the guns when at rest, and the axes of motion, is 24 feet 8 inches. The arc of recoil, of the 8 inch gun, is about 25 degrees, and of the 10 inch gun, is about 26° , when fired with solid shot.

In order to recover the balls uninjured after firing, a butt of earth was erected about 20 yards in front of the guns, near the base of a hill. The butt consists of rough timbers; the lower ends inserted in the ground, and the upper ends supported by clamps of wood. It is sixteen feet wide in front, and fourteen feet deep, and is filled seven feet high with loose earth. Holes for the passage of the balls are made through the timbers in front and

3 inch Columbiad N^o 3.



Scale 1/2.

The water circulation of the interior of the water passed through the core, in the interior of the gun. At the end of this period, an attempt was made to withdraw the gun from the casting, which proved unsuccessful. The contraction of the iron, around the gun, was so firmly, that the upper part of it broke off, leaving the gun embedded in the casting. The stream of water was then diminished to about two feet per minute, which continued to circulate through the core for 48 hours. The supply of water, allotted to and circulated through both the 8 inch and 10 inch guns, was equal, in weight, to the weight of each casting, in about one hour and twenty minutes.

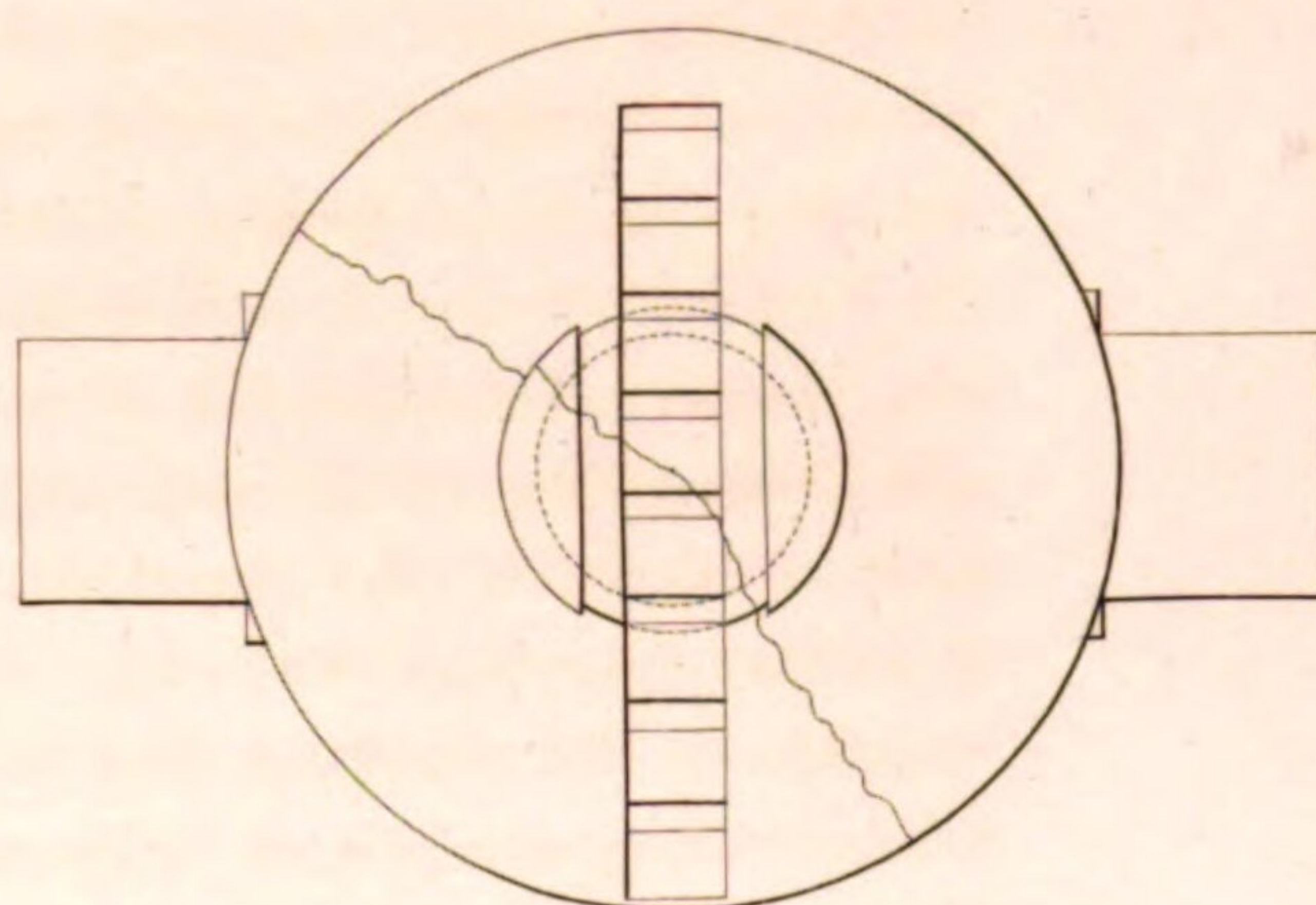
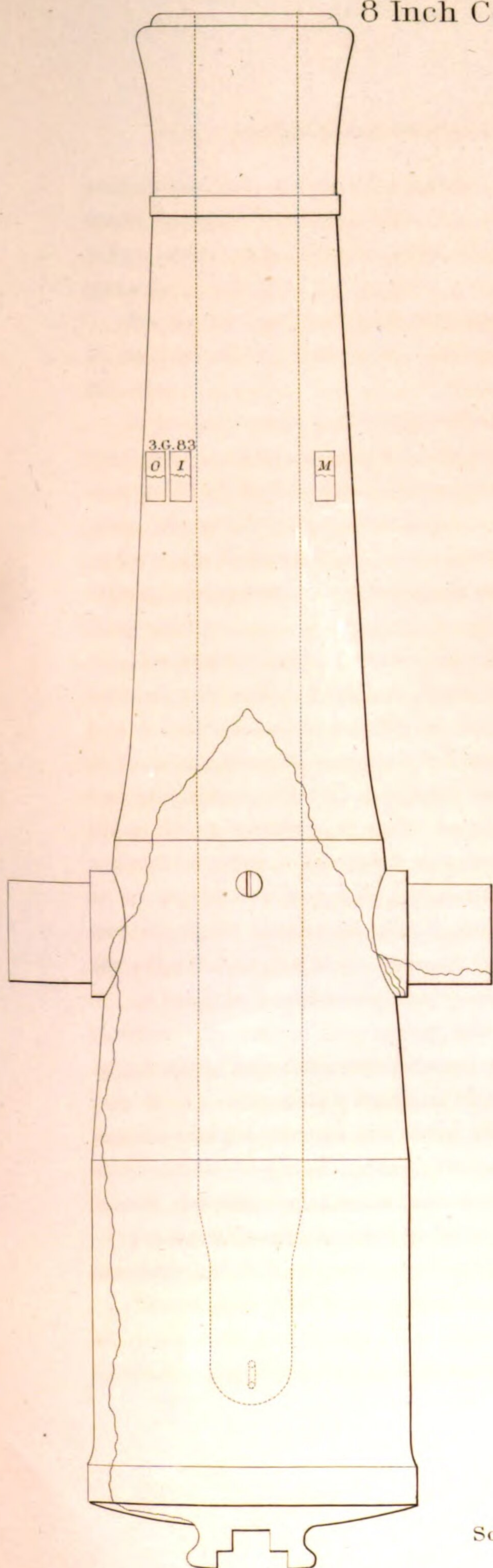
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8 Inch Columbiad N° 3.



Scale $\frac{1}{12}$.

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rear of the butt, about 2 feet high and 3 feet wide, which are filled with brush in order to retain the earth. The balls pass through the butt and lodge against the hill-side beyond, or roll out upon the surface of the ground.

For the protection of the gunners, a barrier similar to the butt was erected in the rear of the guns, with a strong cover of heavy timbers projecting in its rear.

Friction primers were used in firing. They were pulled off by a small cord passing from the guns to the rear of the barrier. The primers were successful, while the vents remained at or near their original diameter; but when the vents became enlarged, it was found necessary to insert wedges in the vent, to prevent the primers being drawn out, unfired. The enlarged volume of the vent, also, frequently prevented the primer from giving fire to the charge.

The suspending apparatus and the butt, were found to answer their purpose very well. Eighty fires per day were easily made, with seven men in five hours, from the 8 inch gun; and with nine men, sixty fires were made in the same time, from the 10 inch gun. The ball was recovered after each fire, and restrapped with a sabot. Six or eight balls were kept in use, by firing each alternately, in order to prevent their becoming too hot for convenient handling. The earth was thrown out of the butt, to such an extent as to require refilling, after firing about ten times with the 10 inch gun, and about 15 times with the 8 inch gun; 15 fires were sometimes made from the 8 inch gun in 30 minutes.

In order to guard against any inequalities; in the strength of the proof charges; the state of the weather, when fired; or in any other circumstances, which might affect the endurance of the guns,—the two guns, making the pair to be compared, were fired alternately, one discharge from each, in regular succession, until one of them burst; when the firing of the survivor was continued by itself alone. The powder, of the cartridges of each pair, was of the same proof range, and taken from the same cask.

Sabots were attached to the balls, in order to fill the space, between the cartridge and ball, in the conic frustrum of the bore.

The charges used in the proof, were as follows:—

Proof Charges.

8 inch.	{ 1st fire—12 lbs. powder, 1 ball and sabot, 1 wad.
	{ 2d fire—15 lbs. powder, 1 shell with sabot.
10 inch.	{ 1st fire—20 lbs. powder, 1 ball and sabot, 1 wad.
	{ 2d fire—24 lbs. powder, 1 shell with sabot.

Service Charges.

8 inch. 10 lbs. powder, 1 ball with sabot.

10 inch. 18 lbs. powder, 1 ball with sabot.

Weight of 8 inch balls $63\frac{1}{2}$ lbs.; of shells $48\frac{1}{2}$ lbs.

Weight of 10 inch balls 124 lbs.; of shells 91 lbs.

The powder was all of Dupont's manufacture, 1837. The mean proof range of that used in firing the 8 inch guns was $297\frac{1}{2}$ yards; and of that used in firing the 10 inch, was 299 yards.

The guns laid on the ground, when fired with the proof charges; and were then placed in the suspending harness; where they remained, during all the firing with service charges.

The number of fires made from each gun, including the proof charges, was as follows, viz:—

8 inch gun, No. 3, cast solid, 73 fires.

8 inch gun, No. 4, cast hollow, 1500 fires.

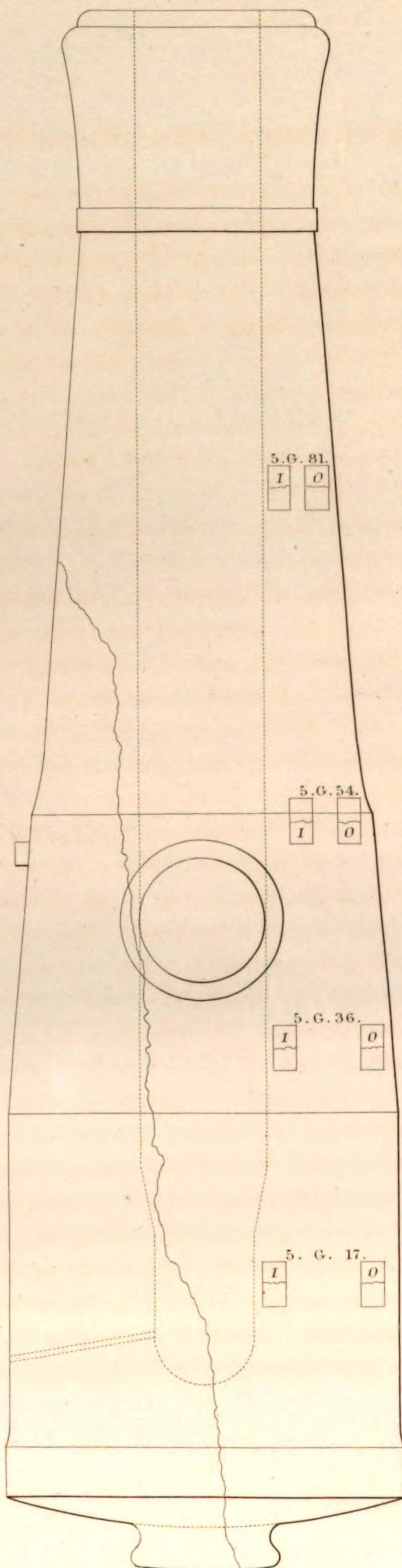
10 inch gun, No. 5, cast solid, 20 fires.

10 inch gun, No. 6, cast hollow, 249 fires.

Each of them, excepting the 8 inch gun, No. 4, cast hollow, burst at the last fire; and that remains unbroken, and apparently capable of much further service.

Two of the guns which burst, split, through the breech and reinforce, in nearly equal parts, the fracture diverging about the trunnions, and terminating on opposite sides of the chase; leaving the latter with the muzzle, in one piece, almost entire. The 10 inch gun, No. 5, separated into two pieces only. The plane of fracture is nearly parallel with the trunnions; the lower part of the breech and reinforce, remains attached to the chase; the upper part, weighing 4400 pounds, was thrown upward, and fell in the rear, about 80 feet distant. In its flight, it broke a limb of a tree, on a hill side, sixty feet above the level of the gun when fired. The plane of fracture in the 10 inch gun, No. 6, is through the vent; and extends forward

10 Inch Columbiad N° 5.



Scale $\frac{1}{12}$.

into the chase, when it breaks off towards the neck. The fracture of the 8 inch gun, No. 3, is diagonal, between the vent and trunnions.

The accompanying sketches, Plates VI, VII, and VIII, exhibit the fractures of the bored guns. The fracture of the 10 inch gun, cast hollow, developed cavities or fissures in the face of the fractured surface, near the front of the chase. The fissures are irregular, penetrating, in some parts, an open channel, half an inch wide and four or five inches in length and depth; in other parts, the metal has a sponge-like appearance, they are from ten to fourteen inches below the neck, or extremest part of the casting, where the iron, by cooling, would become solid entirely through a cross section of the gun. The position of the fissures, marks the place where the iron contained longest liquid, in this section of the casting; for, it is evident, that they were formed by the liquid iron, in this part descending, to supply the vacancies made by the shrinkage upwards. The mass of the metal below being greater, a section of it remained liquid a longer period of time, and until after a cross section at the neck had become solid; and, this solid, intercepting the descent of liquid metal from the sinking head above, the shrinkage below could be repaired from no other part than that where the fissures are found, viz., directly beneath the cross section at the neck, where the metal first became solid throughout.

The area of that part of the cross section, which is outside of the fissures, is seven-tenths of the area of the whole section; and the part within the fissures is three-tenths of the whole. This indicates that seven-tenths of the heat contained in the liquid metal escaped by passing outward, through the exterior surface, to the mould, by which it was conducted off; the remaining three-tenths of the heat passed toward the core, and was carried off by the water.

It is supposed that these fissures did not diminish the endurance of the gun. Upon examination of the surface of fracture, after firing, it appeared, that the gases from the fired gunpowder passed out, mostly, in the parts adjacent to the charge. The fractured surfaces about the chamber, breech, and reinforce, were strongly marked by the powder; while the parts near the edge of the fracture, at the end in front, were nearly free from stain. This indicates that the gun first split through the chamber and breech; and that most of the charge escaped through the fissures in that part, before the fracture had extended to its termination in front.



10 Inch Columbiad No. 3

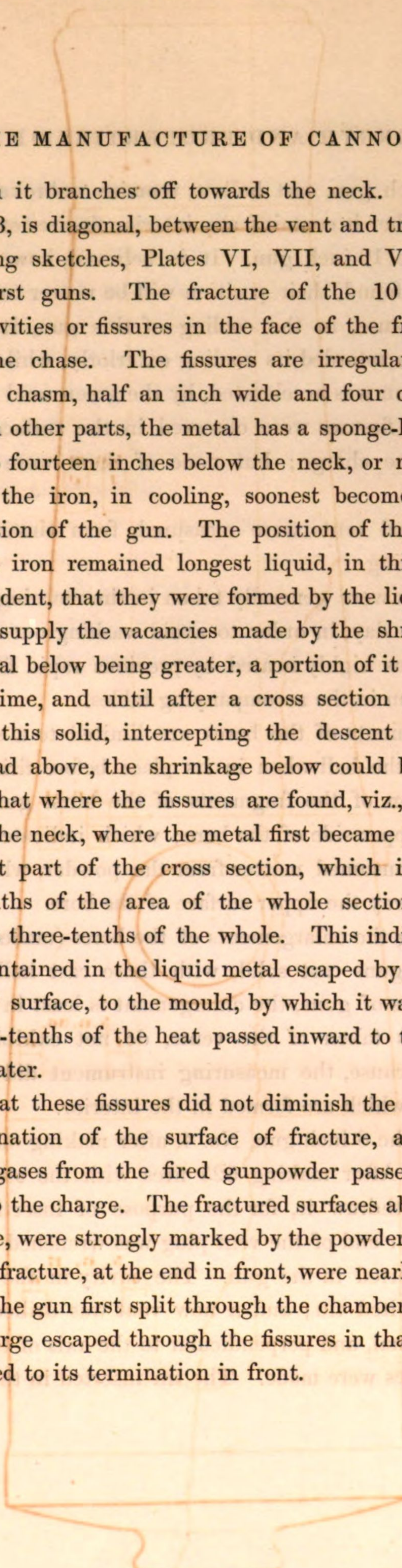


into the chase, when it branches off towards the neck. The fracture of the 8 inch gun, No. 3, is diagonal, between the vent and trunnions.

The accompanying sketches, Plates VI, VII, and VIII, exhibit the fractures of the burst guns. The fracture of the 10 inch gun, cast hollow, developed cavities or fissures in the face of the fractured surface, near the front of the chase. The fissures are irregular, presenting, in some parts, an open chasm, half an inch wide and four or five inches in length and depth; in other parts, the metal has a sponge-like appearance; they are from ten to fourteen inches below the neck, or narrowest part of the casting, where the iron, in cooling, soonest becomes solid entirely through a cross section of the gun. The position of the fissures, marks the place where the iron remained longest liquid, in this section of the casting; for, it is evident, that they were formed by the liquid iron in this part descending, to supply the vacancies made by the shrinkage beneath. The mass of the metal below being greater, a portion of it continued liquid a longer period of time, and until after a cross section at the neck had become solid; and, this solid, intercepting the descent of liquid metal from the sinking head above, the shrinkage below could be replaced from no other part than that where the fissures are found, viz., directly beneath the cross section at the neck, where the metal first became solid throughout.

The area of that part of the cross section, which is outside of the fissures, is seven-tenths of the area of the whole section; and the part within the fissures is three-tenths of the whole. This indicates that seven-tenths of the heat contained in the liquid metal escaped by passing outward, through the exterior surface, to the mould, by which it was conducted off; the remaining three-tenths of the heat passed inward to the core, and was carried off by the water.

It is supposed that these fissures did not diminish the endurance of the gun. Upon examination of the surface of fracture, after bursting, it appeared, that the gases from the fired gunpowder passed out, mostly, in the parts adjacent to the charge. The fractured surfaces about the chamber, breech, and reinforce, were strongly marked by the powder; while the parts near the edge of the fracture, at the end in front, were nearly free from stain. This indicates that the gun first split through the chamber and breech; and that most of the charge escaped through the fissures in that part, before the fracture had extended to its termination in front.



As the 8 inch gun, cast hollow, remains unbroken, it cannot now be ascertained whether it contains any interior fissures or cavities, of the kind developed in the 10 inch gun. It is believed, however, that if any such fissures shall be found, their position will be nearer to the exterior surface of the gun; because, in the cooling of this gun, it was surrounded by heated air, which retarded its cooling exteriorly, while the exterior cooling of the 10 inch gun was accelerated, by the green sand which surrounded it.

A few small fissures were observed in the surface of the bores, about the region of the charge; but none of them were of any considerable extent.

The bores and vents were measured, from time to time, at different periods of the firing.

The measures were generally taken in the morning, before commencing the firing for the day, in order to avoid washing out the bore with water, when the gun was highly heated by previous rapid firing. The measures obtained are given in the accompanying tables.

The enlargements of the bores are limited to a short distance, about the position of the ball when in its place before firing, and it is found, upon examination of the fragments of the burst guns, that the enlargement is on the upper side of the bore; which indicates that it is caused by the gas and unconsumed matter from the powder, which, in passing over the ball, wears away the upper surface of the bore.

On comparing the enlargements of the bores (made by an equal number of fires) of the guns cast solid, with those cast hollow, it will be seen that, in both pairs of guns, the enlargement is least in those cast hollow.

The measures taken of the vents, do not exhibit the whole of the enlargement; because, the measuring instrument did not enter into the sinuous cavities, which are formed in the interior.

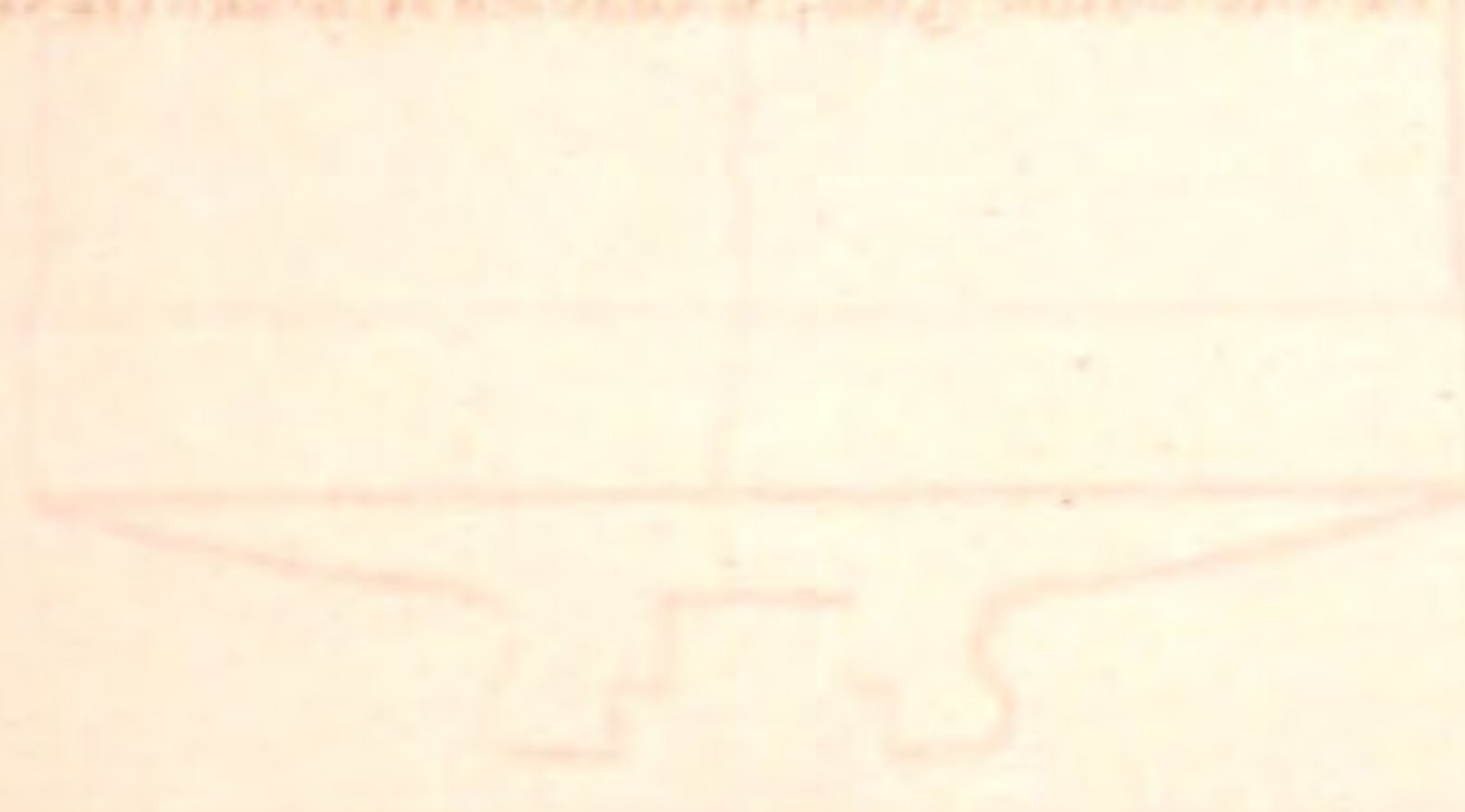
The vent of the 8 inch gun, No. 4, after making 300 fires, was bouched with cast steel. After making 625 fires with the steel vent, an attempt was made to withdraw it, for the purpose of inserting another; but it failed. The upper end of the vent plug was wrenched off, without disturbing the part inserted in the gun. The cavity in the steel vent was then filled up with melted tin; and a new vent was drilled about 30° to the right of the original, and perpendicular to the axis of the bore. With this new vent, 575 fires were made. The tin inserted in the cavity of the steel

vent was several times blown out, and the cavity refilled. Melted zinc was afterwards used instead of tin, and was found to serve much better. The greatest endurance of the tin was 85 fires; and of the zinc, 280 fires. The wear of the cast steel vent is somewhat less, than the wear of those drilled in the metal of the gun; but the difference is not very considerable.

From the effects produced in the course of these trials, it appears that 300 fires is about the maximum number proper to be made with one vent, in guns of such large calibres, and that the vent should then be renewed; not by bouching, but by filling the worn out vent with melted zinc, and by drilling a new vent in another place.

Samples of the iron have been taken from the sinking heads of all the guns, and, also, from various parts of the fragments of those which were broken in the proof; and all have been tested. The position of the several samples, in the guns, is shown in the accompanying sketches, Plates VI, VII, and VIII. The results of the tests are given in the following table:—

The position of the samples in the guns.	
1. Sinking head.	2. Sinking head.
3. Sinking head.	4. Sinking head.
5. Sinking head.	6. Sinking head.
7. Sinking head.	8. Sinking head.
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87. Sinking head.	88. Sinking head.
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91. Sinking head.	92. Sinking head.
93. Sinking head.	94. Sinking head.
95. Sinking head.	96. Sinking head.
97. Sinking head.	98. Sinking head.
99. Sinking head.	100. Sinking head.



Tests of Samples of Iron from 8 inch and 10 inch Columbiads, 1851.

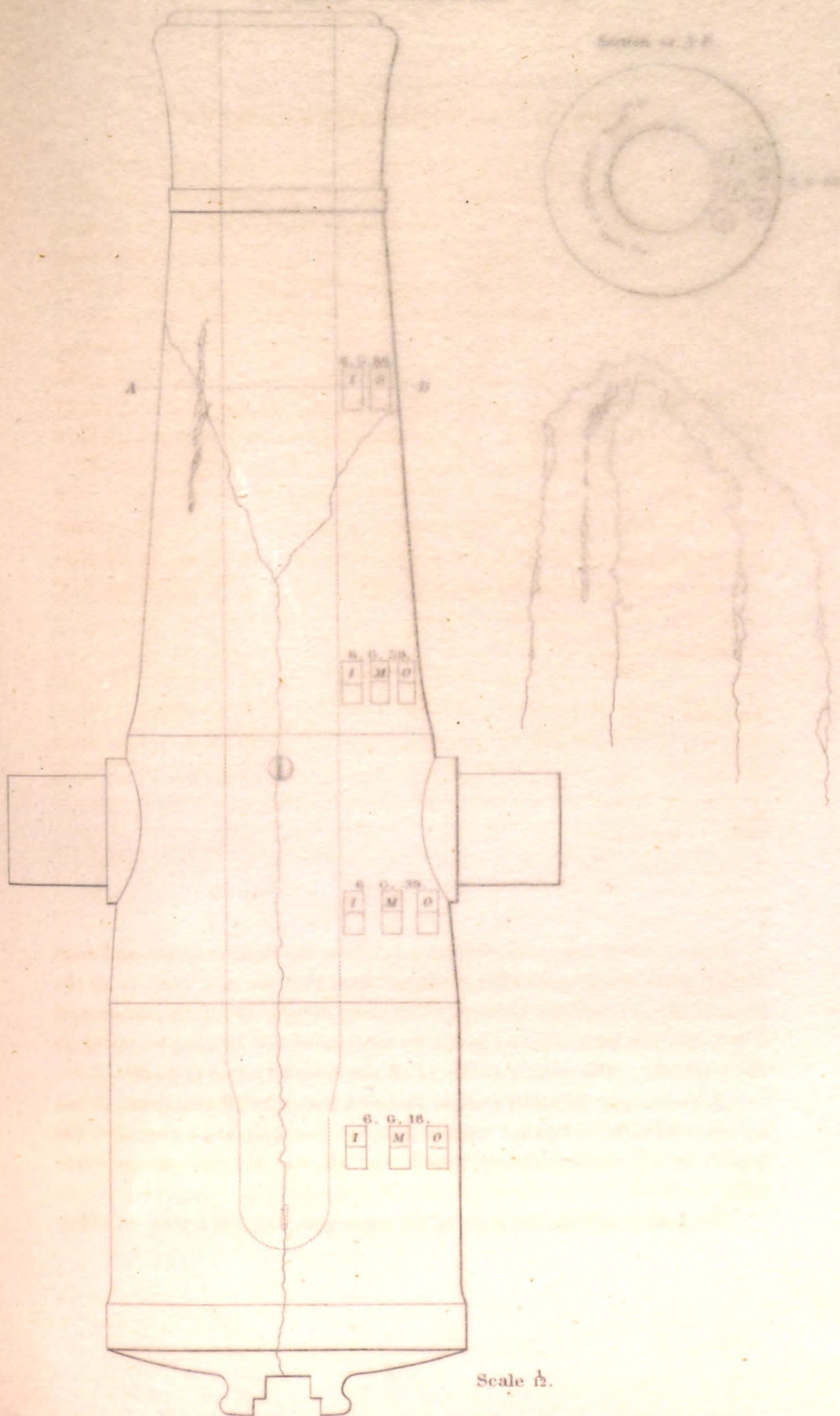
SAMPLES.			POSITION OF SAMPLES IN THE CASTINGS.								MEAN AT EACH CROSS SECTION.	
Castings.	Marks.	Height above rear of base ring. Inches.	OUTSIDE. Near the exterior.		MIDDLE. Between the bore and the outside.		INSIDE. Near the bore.					
			Density.	Tenacity.	Density.	Tenacity.	Density.	Tenacity.				
8 inch guns { Cast solid. { Cast holl'w. {	Head	3. H	121	7.289	36891	—	—	7.295	39031	7.292	37961	
	Chase	3. G. 83	83	7.285	39298	7.287	36170	7.280	38557	7.284	38008	
	Head	4. H	121	7.281	43650	7.287	34540	7.290	36090	7.286	38093	
	Duplicate	4. H. D.	121	7.289	41151	7.278	34278	7.294	36123	7.287	37184	
	Mean of 8 inch guns	—	—	7.286	40247	7.284	34996	7.290	37450	7.287	37811	
10 inch gun cast solid. { Head { Body of the gun {	Head	5. H	122	7.273	40457	—	—	—	—	7.273	40457	
	Body of the gun {	5. G. 81	81	7.271	36147	—	—	7.314	40099	7.292	38123	
		5. G. 54	54	7.289	35289	—	—	7.294	34486	7.292	34887	
		5. G. 36	36	7.275	34216	—	—	7.320	36826	7.297	35521	
		5. G. 17	17	7.292	37654	—	—	7.297	35585	7.295	36620	
	Mean	—	—	7.280	36753	—	—	7.306	36749	7.290	37122	
10 inch gun cast hollow. { Head { Body of the gun {	Head	6. H	122	7.296	40997	7.315	42435	7.306	42425	7.306	41952	
	Body of the gun {	6. G. 86	86	7.300	44425	—	—	7.250	35656	7.275	40040	
		6. G. 59	59	7.297	42038	7.276	34384	7.289	35500	7.287	37307	
		6. G. 39	39	7.301	35304	7.308	37543	7.287	34776	7.299	35874	
		6. G. 18	18	7.294	35884	7.314	39265	7.305	37026	7.304	37392	
	Mean	—	—	7.298	39730	7.303	38407	7.287	37077	7.294	38513	
Mean of seven cross sections, at which samples were taken from each, outside, middle, and inside.			—	—	7.292	39760	7.295	36945	7.293	37214	7.293	37973

These tests of numerous samples taken from the sinking heads, and from various parts of the guns after bursting, show that the iron used, in all the guns, is of very superior quality. The mean density of all the samples, is 7.290, and the least tenacity given by any one of the 38 samples tested, is above 34,000. The mean tenacity of all the samples tested is 37,800.

On comparing the mean results, obtained from the different guns, it will be seen that the difference among them is inconsiderable; and that the quality of the iron contained in each, and all, may be regarded as essentially the same.

The quality in different parts of the same gun, exhibits a marked differ-

10 inch Columbiad N° 6



Specimens of the gun 3.25 inch bore, Columbiads, 1851.

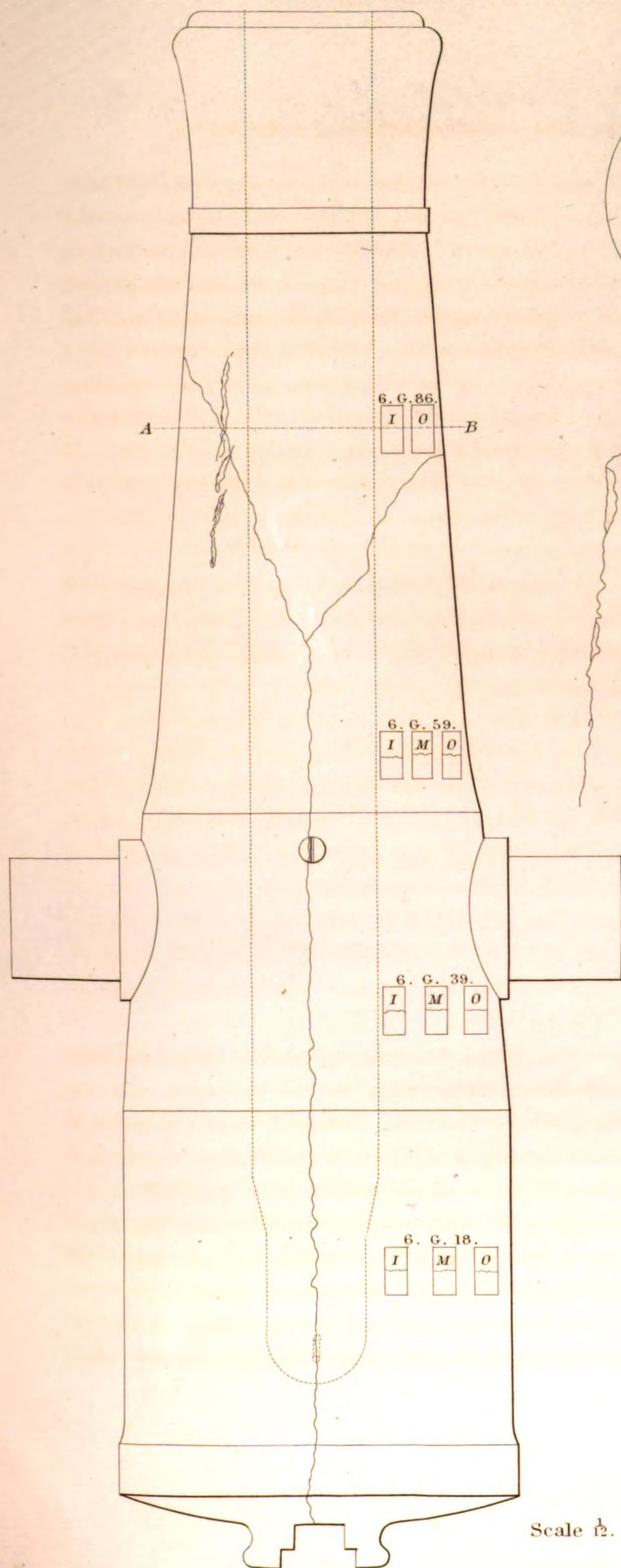
		MEAN AT EACH CROSS SECTION.				MEAN AT EACH CROSS SECTION.			
		OUTSIDE.		INSIDE.		DENSITY.		TENSILE.	
		DIAMETER.	AREA.	DIAMETER.	AREA.	DENSITY.	TENSILE.	DENSITY.	TENSILE.
Gun 3.25 inch bore.	Head	3.25	8.44	2.50	4.91	7.295	39031	7.292	37961
	Shoulder	3.25	8.44	2.50	4.91	7.280	38557	7.284	38008
	Body	3.25	8.44	2.50	4.91	7.290	38690	7.286	38093
	Muzzle	3.25	8.44	2.50	4.91	7.294	38123	7.287	37184
Mean		3.25	8.44	2.50	4.91	7.290	38450	7.287	37811
Gun 3.25 inch bore.	Head	3.25	8.44	2.50	4.91	7.278	40457	7.278	40457
	Shoulder	3.25	8.44	2.50	4.91	7.314	40099	7.292	38123
	Body	3.25	8.44	2.50	4.91	7.294	34486	7.292	34887
	Muzzle	3.25	8.44	2.50	4.91	7.320	36826	7.297	35521
Mean		3.25	8.44	2.50	4.91	7.297	35585	7.295	36620
Gun 3.25 inch bore.	Head	3.25	8.44	2.50	4.91	7.306	36749	7.290	37122
	Shoulder	3.25	8.44	2.50	4.91	7.315	42435	7.306	42425
	Body	3.25	8.44	2.50	4.91	7.250	35656	7.275	40040
	Muzzle	3.25	8.44	2.50	4.91	7.287	34384	7.287	37307
Gun 3.25 inch bore.	Head	3.25	8.44	2.50	4.91	7.287	37543	7.299	35874
	Shoulder	3.25	8.44	2.50	4.91	7.305	37026	7.304	37392
	Body	3.25	8.44	2.50	4.91	7.287	37077	7.294	38513
	Muzzle	3.25	8.44	2.50	4.91	7.293	37214	7.293	37973
Mean		3.25	8.44	2.50	4.91	7.293	37214	7.293	37973

These tests of numerous samples taken from the sinking heads, and from various parts of the guns after burning, show that the iron used, in all the guns, is of uniform quality. The mean density of all the samples, is 7.293, and the mean tensile strength of all the samples tested, is 37,800.

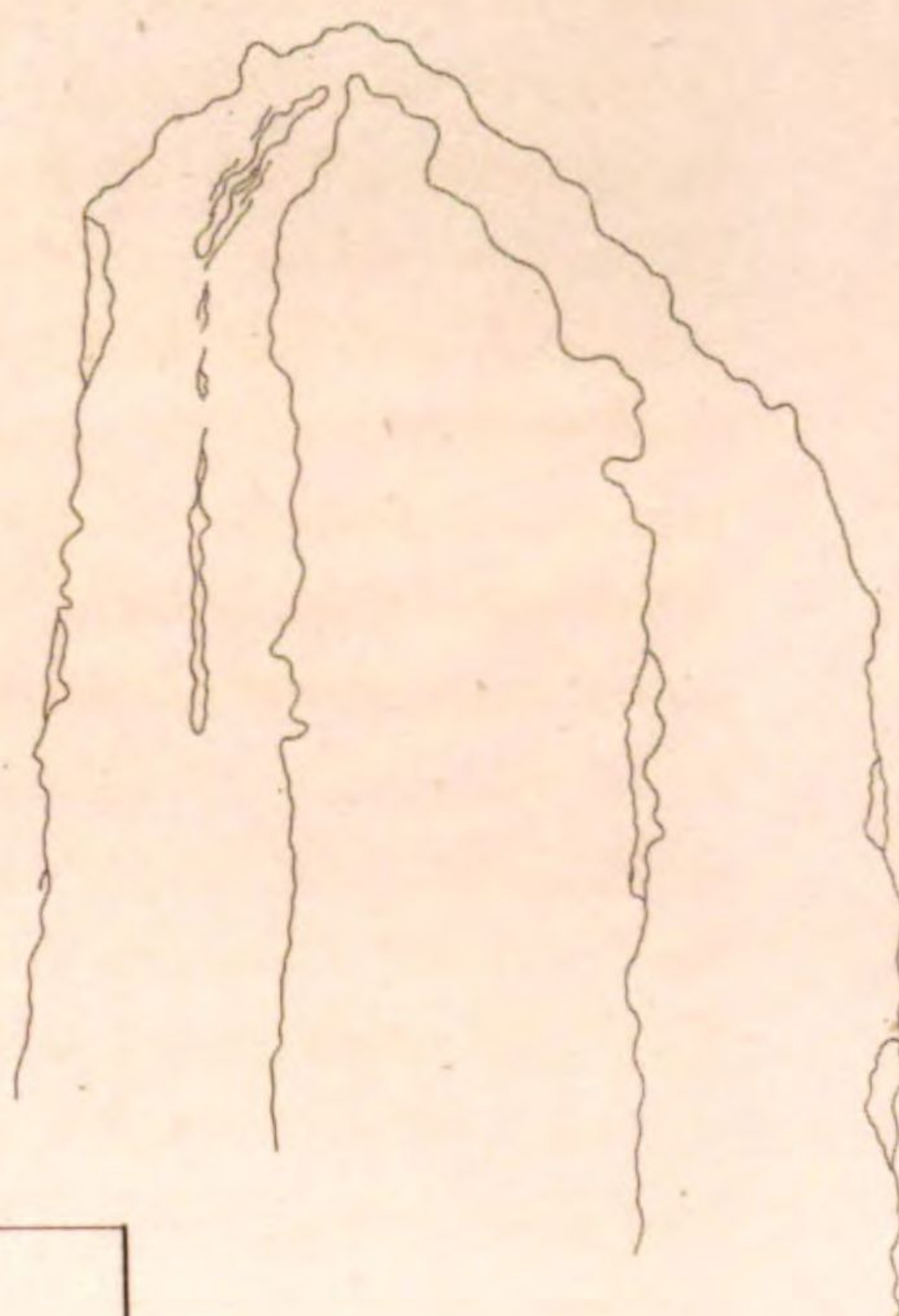
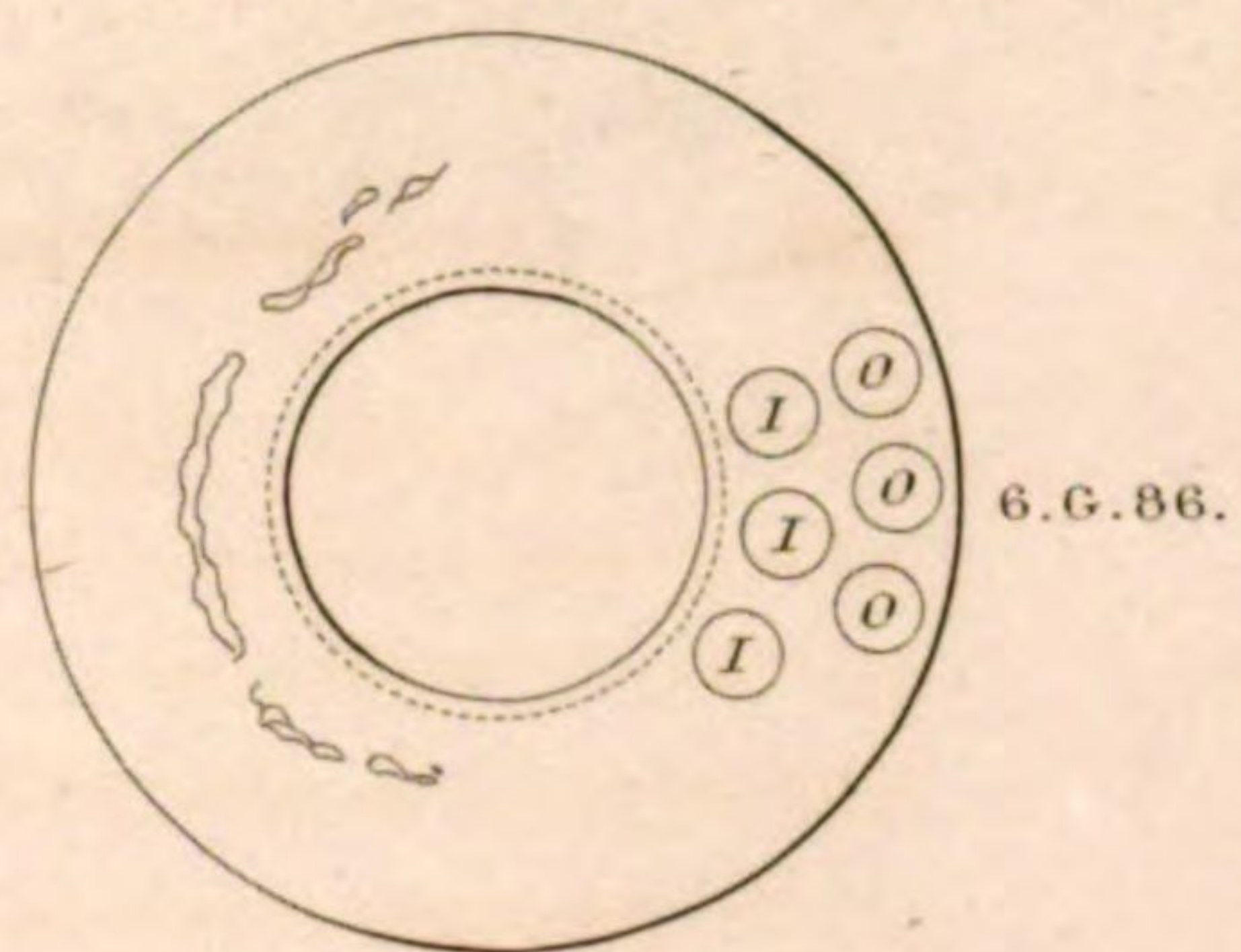
On comparing the mean results obtained from the different guns, it will be seen that the difference in strength is inconsiderable; and that the quality of the iron, considered in each, and all, may be regarded as essentially the same.

The quality in different parts of the same gun, exhibits a marked differ-

10 Inch Columbiad N^o 6.



Section at A B.



Scale $\frac{1}{2}$.

ence. Among the several cross sections at different heights above the breech, from which samples were taken, those taken from the sinking heads, the highest sections, were the best. The next in order of strength, are those from the chase near the neck, and the next, those from the reinforce opposite the chamber. The lowest grade are found about the trunnions, above and below. These distinctions are the same in both the guns thus compared—one cast solid, one hollow—and they appear sufficiently marked to indicate a law, limited, it may be, to guns of like material, and equal bulk.

A difference appears, also, among the samples taken from different parts of the same cross section. But this difference is more strongly marked in the guns cast hollow than in those cast solid. In the 10 inch gun cast solid, the mean tenacity of the samples taken from the outside, and the inside, are almost precisely equal; while in the 10 inch, cast hollow, the outside samples surpass the others considerably. In the cross section of the latter gun, which is in the chase, near the neck, marked 6. G. 86, in the foregoing table, the difference between the outside and inside samples is so great, that it was at first attributed to some possible inaccuracy in testing. Duplicate, and triplicate samples were therefore taken from the same cross section, and tested with similar results. The result given in the table, is the mean of the tests, of three pairs of samples, taken from the same cross section; and it is worthy of note, that this section is the same that contains the fissures, or chasm, before referred to. The relative position of the fissures and the samples, is given in one of the sketches.

Proof bars were cast at each casting of 2d fusion iron, the mean tests of which, are, density 7.230, and tenacity 34500.

The instrument proposed by Lieutenant Rodman, and authorized by the Department, for determining the successive increments of velocity communicated to the ball, in its passage through the bore, when discharged, was applied to the 10 inch gun, No. 6. But it was used only in a few trials, made with a view to observe its performance and to perfect its details. While making some slight modifications which were found to be necessary, the gun burst, which prevented any further trial of the instrument. The few trials made were sufficient to show that the instrument will accomplish, satisfactorily, the purpose designed.

The imperfect observations noted, appear to indicate that the ball acquired its maximum velocity, while passing through about three-fourths

the length of the bore, and that the velocity continued uniform through the remaining fourth to the muzzle.

The arcs of the recoil of the gun, during these trials, were measured; and, the velocity of the balls deduced from them, appears to be about 1530 feet per second. But this, as well as the point at which the ball attained its maximum velocity, being results founded on the inexact data obtained in preliminary trials, are not given as exact determinations.

The relative endurance of the several guns tried, is the most important of the results obtained. And in order to present at one view, the results of all similar trials, made at different periods, they are exhibited together, in the following table:—

Date.	Description.	QUALITY OF IRON USED.		ROUNDS FIRED.	
		Density.	Tenacity.	Cast solid.	Cast hollow.
1849	First pair, 8 inch	7.223	27488	85	251
1851	Second pair, 8 inch	7.287	37811	73	1500
1851	Third pair, 10 inch	7.292	37817	20	249
	Total number of fires	—	—	178	2000
1844 {	Trials made in Boston, { 8 inch both guns cast solid { 10 inch	7.276	26367	731	—
		—	—	612	—

No samples, for testing, were taken from the 10 inch gun, cast solid, in 1844; but the iron was of the same quality as that used in the 8 inch gun, cast about the same time. The charges, used in the last ten fires of the 10 inch gun cast in 1844, were gradually increasing, from the service charges up to 22 pounds of powder and four balls.

It will be seen, that the endurance of the guns cast hollow, greatly surpassed those cast solid, in every case, where both were cast in pairs, at the same time, and from the same material. The difference, in one case, being more than twenty to one; and in the aggregate of all, more than eleven to one. This great difference, occurring in every instance, where guns were cast and tried in pairs, could not, it is believed, have been caused by any accidental circumstances. For the methods pursued to insure an exact equality of material, in both guns of each pair, and for preserving an exact uniformity in the proof of each, seem to forbid the supposition that any unknown inequalities could have existed, either in the casting or the

proving of the guns. The great difference of endurance must therefore be ascribed, to the different methods by which the castings were cooled; and to them alone.

The table, however, presents other incongruous results, which cannot be thus accounted for. The most striking of these will be seen, in comparing the strength of the iron, when measured by its resistance to known weights, under the direct strains of the testing machine, with its resistance when strained by the central force of fired gunpowder. The two guns cast solid, in 1844, give by the testing machine a strength of 26,367 lbs., and the two cast solid, in 1851, give 37,814—while the mean endurance, under the proof firing, of the former is 671 fires, and of the latter, it is 93 fires.

Of the three guns cast hollow, two of them, giving equal strength in the testing machine, differ greatly in endurance; and two, of equal endurance, differ much by the direct tests. But, in this comparison, the guns are of different calibres, which may account, in part, for this diversity.

It will be perceived, also, that in the several pairs, cast solid and hollow, the actual strength of the *iron* in each gun of a pair, as measured by the testing machine, remains the same; while the strength of the *guns*, in the same pair, as measured by the fires endured, differs greatly. From this it appears that the difference in the methods of cooling the casting, while greatly augmenting the strength of the *gun*, in one case, does not, in any, impair or affect the strength of the *iron*. For these, and other apparently discordant or incongruous results, we must seek an explanation in the laws which govern the contraction of iron when cooling.

It is stated by Daniell, that the linear expansion of cast iron, between 62° and its melting point (2786°) is .016389; equal to $\frac{1}{61}$ part of its length. It is known also, that the contraction under equal reductions of temperature, is different, in iron of different qualities. Soft, gray iron, that which contains a high proportion of carbon, contracting least; and that which founders term *high*, which is hard, light and close grained, and contains the least percentage of carbon, contracts the most, other circumstances being equal. The contraction of the same iron is greater or less, according to the greater or less rapidity with which it is cooled. That which is cooled most rapidly contracts most. Every experienced founder is aware of this, and endeavors so to proportion his patterns that all the parts of the same casting may cool equally. In the casting of heavy wheels for

machinery, and for railroad cars, in which the hub is generally more massive than the spokes, or the rim, it is not unusual to see the founder remove the sand from the interior of the hub and pour in water, to hasten the cooling of that part, and to force it to keep pace in cooling, with the spokes and rim. If this precaution be neglected, the spokes may break before the casting becomes cold, or they will be liable to break from a slight shock, afterwards.

The cause of this may be explained, as follows: The rim and spokes, being less massive, and cooling sooner, contract inward upon the hub, while the latter is yet liquid. The contraction, thus far, causes no strain, because the liquid iron of the hub presents no resistance to the spokes. But when the hub becomes solid, its temperature is at the melting point, while the temperature of the rim and spokes is much lower; consequently, a greater amount of contraction must thereafter occur in the former than in the latter. The hub, in its effort to contract its diameter, after the rim and spokes have become cold, pulls the spokes inward, and as this movement is resisted by the rim, the latter is subjected to a force of compression, while the spokes are subjected to a strain of extension. And, as the capacity of cast iron to resist compression is six times greater than its capacity to resist extension, the spokes yield to the tensile strain, and are pulled asunder.

In the application of these laws of contraction to the casting and cooling of cannon, let us suppose that a solid cylinder, of indefinitely large diameter and height, be cast solid and cooled in the usual manner. The iron when cast, is at a temperature much higher than the melting point. It cools down, until the exterior surface comes to the freezing point, when a thin cylinder is formed by congelation, on the exterior, inclosing within it, the liquid iron of higher temperature.

After the lapse of some definite period of time, a second thin cylinder is formed within, and upon the first; and during this period, the first cylinder will have lost some portion of its heat, and its temperature will have fallen below the freezing point, and lower than the second cylinder. Next, a third cylinder is formed within the second, at which time the temperatures, of both the preceding, have fallen still lower, when there will be three cylinders, at three different temperatures. Let us suppose a continuance of this process of successive congelations, until all the liquid iron shall have become solid,

and at the instant when this occurs, that the first or exterior cylinder shall have cooled down to the temperature of surrounding bodies. The difference of temperature between the exterior, and the centre of the casting, will then be about 2700° .

In a casting, thus formed by successive congelations, each layer forming at the freezing point upon its predecessor of a lower temperature, it is supposed, that at the instant when the last portion of its liquid iron became solid, it would be entirely free and unstrained by any contraction; but, as at this time, the exterior of the casting has cooled down to a temperature at which contraction has ceased, and the interior remains just at the melting point, 2700° higher, the contraction due to the latter ($\frac{1}{61}$ part of its linear dimensions) is yet to occur in the centre; *after* the exterior has ceased to contract. The effect of such a contraction *must be*, to exert a strain of compression on the exterior, and one of elongation in the interior. The neutral line, or the part remaining unstrained by either compression or elongation, it is supposed, would be, at about one-seventh of radius from the exterior surface. The extent of contraction in a 10 inch gun, cooled, as above supposed, with a maximum difference of temperature, would be about two inches in length, and half an inch in diameter; and, $\frac{6}{7}$ of the latter, would be in a direction from the centre towards the exterior and tending to split open the gun.

The above supposes an extreme case, in which a maximum difference of temperature between the exterior and interior occurs, a condition which never exists in practice. But it serves, however, to explain the law which governs the contraction of iron and, what is believed to be, its injurious effect in castings which are unequally cooled. There is no doubt of the fact, that cast iron is injuriously strained more or less, by unequal contractions, when unequally cooled. What remains undetermined, is the exact measure of the consequences of such strains. The consequence, in the extreme case supposed, would undoubtedly be to produce rupture, in the interior of the casting. And in all heavy cannon cast solid, a strain of this kind, of greater or less force, is believed to exist, and that it is exerted in a direction tending to assist the central force of the charge in bursting the gun. In the case of the 10 inch gun cast solid, which burst at the twentieth fire (being of large diameter and made of very high iron—both contributing to a large contraction) it is supposed that the strain thus

produced, was nearly sufficient, of itself, to split the gun, and that a few shocks only, from the firing, were needed to complete its destruction.

The greater the difference of temperature between parts of the same casting while cooling, the greater will be the strain. Therefore, in casting solid guns, the aim should be to retard the exterior cooling as much as practicable, in order to reduce the difference of temperature to a minimum. Heating the gun mould and the pit which contains it, as much as they will safely endure, before casting, and continuing this heat until that of the casting falls to an equality with it, is suggested, as the best method of accomplishing this purpose. It is believed, however, that such a slow cooling will materially affect the quality of the iron, by reducing both its density and tenacity.

The contraction of *high*, hard and strong iron, is greater than that of soft, gray and less tenacious iron, and consequently the injurious strain in the former is greater than in the latter. To the influence of this law, and its consequences, we may in a great measure attribute the extraordinary results before mentioned, respecting the two guns cast solid in 1851, compared with the similar guns, cast in 1844. The former were made of the *high* iron, giving a mean test strength of 37,814 pounds per square inch, and a mean endurance of 46 fires: the latter were made of the *lower* iron, giving a test strength of 26,367 lbs., and an endurance of 671 fires. From this it appears, that a reduction of strain in the *casting*, is of more practical value, than an increased strength of the *iron*: and it follows, that in order to diminish the strain of contraction, in large guns, cast solid, we should use the softer and less tenacious qualities of iron.

If these conclusions are well founded, as they are believed to be, we must, in making large guns, cast solid, select a softer and weaker iron, to commence with, and then impair its density and strength, by a very slow process of cooling—in order to prevent the dangerous consequences of straining the iron by unequal contractions in cooling. This involves an abandonment of the harder and the stronger iron, because of our ignorance in the art of managing it. These are conditions which should not be willingly submitted to; but, efforts should rather be made to learn how we may so manage the best material, that it shall retain its superiority in the completed weapon. The obstacle in the way, is the irresistible law of con-

traction under differences of temperature, and the remedy, it is believed, can be found only, in conforming to that law.

The method devised by Lieutenant Rodman, for accelerating the cooling of the interior of guns, by passing a stream of water through them, and for retarding, at the same time, the cooling of the exterior, by surrounding it with heated air, appears to lead in the right direction, even if it does not fully accomplish the purpose designed. This opinion is founded upon all of the results obtained from the guns cast in pairs, and its justness appears to be amply confirmed by the trials of the 8 inch guns. The iron used in this pair of guns was both hard, and strong, in a high degree. The cause of the early failure of that cast solid, at the 73d fire, is the same as that assigned for the failure of all heavy guns thus cast, viz., the strains of contraction in cooling. The cause of the prolonged endurance of that cast hollow, 1500 fires, and remaining unbroken, and (we may almost add) indestructible by service charges, is, that the strain of contraction was prevented by the interior cooling, and the iron thus left free to resist, with all its original tenacity, the central force of the charges; and further, the interior cooling may have been sufficient to reverse the direction of the strains, to such extent, as placed the iron in the condition best adapted to resist the strains of central forces, according to the theory of Barlow.

But whatever may be the value of the causes here assigned for the difference of results, the material fact established is, that with iron of the highest qualities—hardness to resist wear, and tenacity to resist rupture—a gun cast solid proved unfit for service, while a gun cast hollow, from the same material, at the same time, gave an unexampled endurance. This fact should not be undervalued. Such a result is of too much importance to be passed by, without attentive consideration. There is no just reason why, with more experience and better knowledge, we may not, always, with similar materials command similar results.

The failure to obtain similar results with the 10 inch gun, made of the same materials, and tried afterwards, is sufficient cause for doubts, but not for final conclusions, in the face of such results as were obtained from the 8 inch guns.

The lower endurance of the 10 inch gun cast solid, may be ascribed in part, to its greater bulk, causing a greater contraction: and also, to a disproportioned and higher strain, given by the charges of the 10 inch gun, than

is given by those of the 8 inch. The same causes may have affected the endurance of the 10 inch gun cast hollow. And another may be added; that of the imperfect manner in which the exterior cooling of this gun was retarded. These several causes it is believed, all tended towards lessening the endurance of the 10 inch guns, but, to what extent, must be conjectural only.

On a review of all the facts and considerations herein presented, it appears necessary that a further trial, of another pair of 10 inch guns, should be made.

The iron, in both, to be of the same kind as was used in the last 10 inch guns. One of them to be cast solid, and its exterior cooling to be retarded, by surrounding it with heated air in the most effective manner practicable; the other, to be cast hollow, and the principle of interior cooling by water, while retarding the exterior cooling, to be carried out to its full extent; as it was in the case of the 8 inch cored gun.

Such a trial would serve to demonstrate whether or not the principle of interior cooling, which proved so successful in the 8 inch gun, is equally applicable in 10 inch, or in larger guns; and also, whether the slow cooling of solid guns, by heating the exterior, will so reduce the strains of contraction, in iron of high quality, as will permit the employment of the strongest iron in casting guns solid. These are both points of the highest importance in the art of casting cannon; and they are both left in doubt, by the results of the late trial of 10 inch guns. If in that trial, the results had corresponded with those given by the 8 inch, all doubts would have been removed, and the important purpose for which the experiments were undertaken, would have been accomplished. It therefore seems indispensably necessary that another trial, of the kind suggested, should be made, in order to arrive at a correct conclusion.

It is well known that the difficulty of making cannon, which shall be equally enduring and safe, with equally proportioned charges, increases as their calibres increase. The necessity for devising methods by which this difficulty may be successfully overcome, is becoming more and more important.

There is a tendency in our own service, and elsewhere, to enlarge the calibres of cannon in both ships and forts, which is rapidly developing itself everywhere. In our own forts, the calibres have advanced from a 24 pdr.,

the maximum of 1820, to the 10 inch, or 125 pdr., of 1850; and an essay has been made, not unsuccessfully, towards a 12 inch, or 225 pdr. And, it may be safely predicted, that the end is not yet reached in this direction.

The plan of interior cooling has, thus far, been tried only in 8 inch and 10 inch columbiads. As the 32 pdr. guns constitute a very large proportion of the armament of forts and ships, at present, and may do so for some time hence, it seems to be proper that a pair of guns of this calibre be tried in the same manner.

It is therefore proposed, that two 32 pdr. guns be cast of the same iron, at the same time, one to be cast solid and the other hollow, and that each be cooled in the same manner, as suggested for the 10 inch guns; and that both be proved to extremity, by continuous service charges.

An explanation of the cause, why the strain of contraction, in a large mass of iron, caused by unequal temperatures in cooling, affects so materially its power of resisting a central force—while it leaves unimpaired the strength of a small sample, detached from the same mass—may be added here to supply an omission elsewhere. The cause is conceived to be this. Any material being under a strain, of any extent, within the limits of its elasticity, will, on being relieved from the strain, restore itself to its original condition. The separation of the small sample, from the large mass, gives this relief to the former, which is then restored to its original condition, and to all the power of resisting strains due to its tenacity.

The general theory of the law, which governs the strains produced on any material, by the action of a central force, and, of its consequences, as suggested by Barlow, has been discussed by Lieut. Rodman, in a separate communication. It is referred to here, as being intimately connected with the general purpose of these experiments, and as expressing views in which I concur.

Respectfully submitted,

W. WADE.

January 24, 1852.

TO THE COLONEL OF ORDNANCE, WASHINGTON.

8 Inch Columbiad No. 3, Cast Solid. Greatest Enlargement of the Bore, above its Original Diameter, after the 2d and 72d Fires; expressed in thousandths of an inch.

Distance from muzzle.	2d.	72d.
Inches.		
10	0	0
20	0	0
30	0	0
40	0	0
50	0	0
60	0	0
70	0	0
80	0	1
85	0	1
90	1	1
91	1	2
92	2	3
92½	5	9
93	5	12
93¼	5	12
93½	5	12
93¾	5	12
94	5	12
94¼	4	12
94½	4	16
94¾	3	14
Chamber		
101	3	9
104	5	10
107½	4	8

August 30, 1851. Burst at 73d fire.

8 Inch Columbiad No. 4, Cast Hollow. Greatest Enlargement of its Bore, above its Original Diameter, after the under-mentioned Fires; expressed in thousandths of an inch.

Distance from muzzle.	2d.	72d.	152d.	223d.	300th.	375th.	450th.	530th.	610th.	690th.	770th.	850th.	925th.	1005th.	1085th.	1165th.	1245th.	1330th.	1415th.	1500th.	
																				Horizontal.	Vertical.
10	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	3	3	3	3	3
20	0	0	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3
30	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
40	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
50	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
60	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
70	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
80	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
85	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
90	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
91	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
92	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
92½	2	2	3	4	5	6	7	8	17	17	17	17	17	17	17	17	17	17	17	17	17
93	2	2	3	4	5	6	7	8	17	17	17	17	17	17	17	17	17	17	17	17	17
93½	3	3	4	5	6	7	8	17	17	17	17	17	17	17	17	17	17	17	17	17	17
93¾	3	3	4	5	6	7	8	17	17	17	17	17	17	17	17	17	17	17	17	17	17
94	5	5	8	14	19	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
94½	5	5	8	14	19	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
94¾	5	5	8	14	19	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
95	5	5	8	14	19	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
Chamber																					
101	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
104	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
107½	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Discontinued firing, October 2, 1851.

The enlargements recorded were all measured in the vertical plane of the bore, excepting those in one of the columns under the head of 1500 fires, which were measured in the horizontal plane. Horizontal measures were taken at other fires; but they are omitted, as those taken after the last fire are sufficient to exhibit the proportional enlargements in the vertical and horizontal planes.

Diameters of Vents measured after the number of Fires stated in the several Columns.

Vents of 8 Inch Columbiads.

Inches from exterior orifice.	NO. 3, CAST SOLID.	NO. 4, CAST HOLLOW.						
		FIRST VENT. IN METAL OF GUN.		VENT IN CAST STEEL BOUCHE.			SECOND VENT. IN METAL OF GUN.	
		72d fire.	150 fires.	300 fires.	300 fires.	470 fires.	625 fires.	160 fires. 575 fires.
1	.20	.22	.26	.23	.26	.35	.20	.33
2	.21	.23	.29	.24	.27	.37	.22	.38
3	.22	.24	.32	.24	.28	.40	.23	.38
4	.23	.24	.34	.25	.28	.41	.23	.38
5	.24	.25	.37	.23	.31	.38	.23	.42
6	.25	.24	.38	.25	.37	.70	.24	.49
7	.25	.26	.42	.27	.35	.53	.27	.52
8	.25	.24	.44	.28	.38	.53	.28	.40
9	.21	.25	.39	.29	.38	.67	.25	.45

Vent of 10 Inch Columbiad, No. 6, Cast Hollow.

Inches from exterior orifice.	DIAMETERS.	
	Original.	After 200 fires.
0	.20	.22
1	.20	.23
2	.20	.24
3	.19	.25
4	.19	.25
5	.18	.25
6	.18	.26
7	.17	.27
8	.17	.28
9	.16	.29
10	.15	.28
11	.15	.30

Greatest Enlargement of Bores, above their Original Diameters, after the under-mentioned Fires; expressed in thousandths of an inch.

10 INCH COLUMBIAD, NO. 5, CAST SOLID.			10 INCH COLUMBIAD, NO. 6, CAST HOLLOW.									
Distance from muzzle.	2D FIRE.		2D FIRE.		28TH FIRE.		88TH FIRE.		136TH FIRE.		187TH FIRE.	
	Hori- zontal.	Ver- tical.	Hori- zontal.	Ver- tical.	Hori- zontal.	Ver- tical.	Hori- zontal.	Ver- tical.	Hori- zontal.	Ver- tical.	Hori- zontal.	Ver- tical.
10	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0
88	0	0	0	0	0	0	0	0	0	0	0	2
89	0	7	0	0	0	0	0	0	1	0	1	4
90	1	13	0	0	0	1	0	1	1	1	2	5
90½	1	17	0	0	0	2	1	2	2	3	3	7
91	1	15	0	0	1	2	3	3	4	7	5	13
91¼	1	13	0	0	1	2	4	4	4	9	7	15
91½	1	14	1	1	1	2	3	4	4	12	8	22
91¾	1	15	1	2	2	2	6	6	8	15	13	34
92	2	15	1	2	3	4	7	9	10	23	18	31
92¼	2	15	0	2	2	6	7	13	11	25	17	37
92½	1	13	0	2	1	7	6	12	12	24	17	35
92¾	1	12	0	0	1	1	3	7	6	14	13	20
Chamber												
100½	2	2	2	3	2	3	3	3	3	3	4	3
103½	2	2	2	3	2	3	2	3	2	3	3	3
106½	2	2	2	3	2	3	2	3	2	3	3	3

10 inch Columbiad No. 5, burst at the 20th fire, October 9, 1851.

10 inch Columbiad No. 6, burst at the 249th fire, October 18, 1851.

REPORT

ON THE

CAUSES OF DIFFERENCE IN THE ENDURANCE OF CANNON,

CAST SOLID, AND CAST HOLLOW,

AND

COOLED FROM THE EXTERIOR, AND INTERIOR.

PITTSBURG, 1851.

REPORT

ON THE

CAUSES OF DIFFERENCE IN THE ENDURANCE OF CANNON, WHEN
CAST SOLID, AND CAST HOLLOW, AND, COOLED FROM THE EXTE-
RIOR, AND THE INTERIOR.

ALLEGHANY ARSENAL, *November 30, 1851.*

COL. H. K. CRAIG, ORDNANCE OFFICE, WASHINGTON CITY, D. C.

SIR: Although Major Wade will furnish you with a report in full, of the manufacture and proof of the experimental 8 and 10 inch guns, recently made at the Fort Pitt Works, yet I deem it proper to submit what I consider to be the causes of the very marked differences in the endurance of these guns; and, in order to render these causes more apparent, it will be necessary to consider the law governing the strain, produced on any material by the action of a central force, as well as the consequences which flow therefrom.

Barlow shows that the strain produced on any material, by the action of a central force, diminishes as the square of the distance from the centre increases. His demonstration is based upon the hypothesis that the area of the cross section, of the body to which the force is applied, remains the same before and after the application of the central force. So that, if r = radius of bore, R = radius of exterior, b = increase of interior radius, and B = that of exterior radius, we shall have the equation $\pi (R^2 - r^2) = \pi (\overline{R + B}^2 - \overline{r + b}^2)$, or $R^2 - r^2 = R^2 + 2BR + B^2 - r^2 - 2br - b^2$; but since B and b are very small fractions of R and r , their squares may be neglected, and we shall have $BR = br$, (3). But, the strains produced on any two pieces, of the same material, will be proportional to the increase in length divided by the original length of each respectively,—the absolute

strain, for a given increase in length, depending on the co-efficient of elasticity of the material strained; so that, if $\frac{B}{R}$ = strain on the exterior, then $\frac{b}{r}$ = that on the interior; but, if in equation (3) we multiply and divide the 1st member by R , and the 2d, by r , we shall have $R^2 \frac{B}{R} = r^2 \frac{b}{r}$, or the proportion $R^2 : r^2 :: \frac{b}{r} : \frac{B}{R}$, or, the strain diminishes as the square of the distance from the centre increases.

Now let us suppose a gun perfectly free from strain, and apply a central force until the interior is brought to the breaking strain; and let the radius of the bore be the unit of measure, and a = tensile strength of the square unit. Then, if the gun be one calibre in thickness, the distance from the centre of the bore to the exterior will be 3, and the strain will diminish, in obedience to the above demonstrated law, until that at the exterior will be $\frac{1}{9}$ of that at the interior, and the effective resistance which the gun will be capable of offering to a central force, will be the sum of all these strains. In order to determine this sum, let it = u , and let x = any variable distance from the centre, and we shall have, for the strain upon any one of the infinitely thin cylinders of which the thickness of the gun is composed, $a \frac{dx}{x^2}$, and for the sum of all these strains, $u = a \int \frac{dx}{x^2} + c = -\frac{a}{x} + c$; now to determine the value of (c) , let $u = 0$, and $x = 1$, (since when $x = 1$, the sum of the strains = 0), and we find $c = a$, and, $u = -\frac{a}{x} + a$; and integrating between the limits $x = 1$, and $x = 3$, we have $u = a - \frac{a}{3} = \frac{2}{3} a$; or, the effective resistance, of a gun one calibre in thickness, will be two-thirds ($\frac{2}{3}$) of that, which half a calibre in thickness *would* offer, if the strains were all equal as in tensile strain.

The above results suppose the gun to be entirely free from strain before the application of the straining force, a condition which could only be obtained by allowing it an infinite length of time to cool. For, it never could cool without allowing the surface to fall to a temperature below that of the interior of the metal, and, since iron diminishes in bulk as its temperature decreases, it follows that a gun cast solid, and cooled, of necessity, from the exterior and in a limited time, will be thrown upon a strain—the exterior

being under a force of compression, while the interior is under one of elongation—and the greater the difference of temperature between the exterior and interior, during the process of cooling, or the more rapidly the cooling is effected, the greater will be this strain.

Now, let us suppose a central force applied to a gun thus strained, and bear in mind the law of strain, as above demonstrated: the interior is already under a force of elongation, while the exterior is under one of compression: the action of the central force develops (in a gun, one calibre thick) *nine* times the strain on the interior that it does on the exterior, *independent of previous strain*, so that we have the effort of the exterior, to free itself from the force of compression to which it has been subjected in cooling, combined with the central force, to break the interior; and the wonder is, that guns thus strained, in cooling, endure as long as they have been found to do.

It is also known that the contraction of iron, under equal degrees of reduction in temperature, increases as the iron approaches a state of purity, or, as the percentage of carbon diminishes; so that what is termed *very high* iron cannot be cast into shapes—where the times of cooling of the different parts are unequal—with any certainty of enduring the strain to which it is thus subjected, and large rolls for rolling iron have been known to split open, longitudinally, from this cause.

Now the iron of which the experimental guns were made, was what is termed *high* iron, all of it having been melted once and run out into pigs, and a portion of the pigs again remelted, before being melted for casting the guns; this degree of purity having been found to produce the greatest tensile strength attainable with this iron, without risk of cavities in the castings.

This iron contracted more, in cooling, than that which we have been in the habit of using at this foundry, as shown by the fact, that the 8 inch guns cast from this iron, and off the same pattern as heretofore used, were from .10 to .15 of an inch less in diameter, than those from other iron. The small endurance of the 8 inch solid gun can only be explained or accounted for, by reference to the above stated laws, deductions, and facts. These, to my mind, do satisfactorily account for the early bursting of the solid gun, and for the great endurance of the hollow one; for, the same causes which contributed to the bursting of the one, *being reversed in effect*, contributed to the endurance of the other. The solid one, cooling from the exterior in an open pit, and being of iron that contracted very much in cooling, was doubt-

less thrown upon a very heavy strain, the exterior being compressed, and the interior elongated; while the hollow one, being rapidly cooled from the interior, and prevented from cooling from the exterior, was thrown upon a strain just the reverse of the solid one. And, I have no doubt that the interior of the solid gun was broken *before* the exterior was relieved from the pressure to which it had been subjected in cooling, while in the hollow gun, the object of my improvement was in part, if not fully, attained, viz: to throw the gun upon a strain, such that under the action of the law of strain, as stated above, each one of the infinitely thin cylinders composing the thickness of the gun, shall be brought to the breaking strain *at the same instant*. This condition would give us for the effective resistance to rupture, in a gun 1 calibre thick, $2a$, instead of $\frac{2}{3}a$ —which, has been shown to be all that could be obtained from a gun free from strain by cooling—and is, doubtless, *much more* than can possibly be attained in practice. The higher the metal, and the greater its contraction in cooling, and the more rapidly the gun is cooled, the further will the solid one fall below $\frac{2}{3}a$, and the more nearly will the hollow one approach $2a$, provided the cooling be effected from the interior; also, the greater the diameter of the solid gun, the greater will be the strain from cooling. It is not considered practicable to cool a gun so rapidly from the interior as to cause rupture to commence on the exterior.

The less endurance of the 10 inch hollow gun than that of the 8 inch hollow one, is accounted for by the fact, that the 10 inch gun had no fire on the exterior of the flask while cooling, it having been rammed up in the pit, where it was supposed, at the time of casting, the heat of the gun would have been retained by the sand, until the interior should have been cooled by the circulation of water through the core barrel.

This supposition was found to be erroneous on digging out the sand, as its temperature was found to be much lower than had been expected.

The less endurance of the 10 inch solid gun than that of the 8 inch solid one, is attributable to the increased strain to which it was subjected in cooling, arising from its increased diameter; and, to the greater pressure of the gas in firing, which is, directly, as the diameter of the bore; since the weight of the shot increases as the cube of the diameter, while the area of its great circle, or the surface pressed, only increases as the square of the diameter.

The 10 inch guns were both rammed up in the same pit for casting. They were thus treated on account of the smallness of the flasks, it having been considered unsafe to cast without this precaution, as it was feared that the great body of heat in these guns would strike through the small thickness of sand, and weaken the flasks so much as to cause them to give way and let the metal out of the moulds.

The flask being rammed up in the pit, of course rendered it impossible to apply heat to the exterior during the process of cooling, so that I do not consider my mode of cooling to have been properly applied in this case, (although it was intended to be at the time of casting), nor do I consider the endurance of this gun as any criterion, or measure, of what can be attained by a proper application of the new mode of cooling; though it certainly does show that, as far as this mode was applied, it was beneficial, as the *ratio* of endurance of the *pair* is about $12\frac{1}{2}$ per cent. in its favor. I have the utmost confidence that with iron of the same quality as that used in these guns, and a proper application of the new mode, a 10 inch gun may be made to endure from 1000 to 1250 fires.

I am very respectfully, sir, your obedient servant,

T. J. RODMAN.

REPORT

ON THE

EFFECT OF TIME IN REMOVING STRAINS CAUSED

BY THE

UNEQUAL COOLING OF HEAVY IRON CASTINGS.

OCTOBER, 1852.

REPORT

REPORT

ON THE

EFFECT OF TIME IN REMOVING STAINING CAUSED

by the action of the atmosphere on the surface of the metal. The results of the experiments conducted by the author are given in the following table.

EXPERIMENTAL COEFFICIENT OF HEAVY IRON CASTINGS

The mechanical tests and the experiments in regard to the effect of time on the surface of the metal are as follows:

OCTOBER, 1883.	
1st and 2nd series.	1st and 2nd series.
3rd and 4th series.	3rd and 4th series.
5th and 6th series.	5th and 6th series.
7th and 8th series.	7th and 8th series.

The first series of experiments was conducted on a piece of heavy iron casting, and the results of the experiments were the same in all. It will be seen that the surface of the casting was, with a short interval of time, in a state of oxidation, and that the oxidation was, in some cases, of a deep red color. The second series of experiments was conducted on a piece of heavy iron casting, and the results of the experiments were the same in all. It will be seen that the surface of the casting was, with a short interval of time, in a state of oxidation, and that the oxidation was, in some cases, of a deep red color. The third series of experiments was conducted on a piece of heavy iron casting, and the results of the experiments were the same in all. It will be seen that the surface of the casting was, with a short interval of time, in a state of oxidation, and that the oxidation was, in some cases, of a deep red color. The fourth series of experiments was conducted on a piece of heavy iron casting, and the results of the experiments were the same in all. It will be seen that the surface of the casting was, with a short interval of time, in a state of oxidation, and that the oxidation was, in some cases, of a deep red color. The fifth series of experiments was conducted on a piece of heavy iron casting, and the results of the experiments were the same in all. It will be seen that the surface of the casting was, with a short interval of time, in a state of oxidation, and that the oxidation was, in some cases, of a deep red color. The sixth series of experiments was conducted on a piece of heavy iron casting, and the results of the experiments were the same in all. It will be seen that the surface of the casting was, with a short interval of time, in a state of oxidation, and that the oxidation was, in some cases, of a deep red color. The seventh series of experiments was conducted on a piece of heavy iron casting, and the results of the experiments were the same in all. It will be seen that the surface of the casting was, with a short interval of time, in a state of oxidation, and that the oxidation was, in some cases, of a deep red color. The eighth series of experiments was conducted on a piece of heavy iron casting, and the results of the experiments were the same in all. It will be seen that the surface of the casting was, with a short interval of time, in a state of oxidation, and that the oxidation was, in some cases, of a deep red color.

REPORT

ON THE

EFFECT OF TIME IN REMOVING STRAINS CAUSED BY THE UNEQUAL COOLING OF HEAVY IRON CASTINGS.

PITTSBURG, *October 12, 1852.*

COLONEL H. K. CRAIG.

SIR: Since my report of the 24th of January last, on the manufacture and extreme proof of 8 and 10 inch Columbiads, Major Bell has completed the extreme proof of two 8 inch Columbiads cast in 1846. The extraordinary endurance of these two guns induces me to submit some further considerations upon the subject.

The mechanical tests and the endurance in firing, of the three 8 inch Columbiads, are as follows:—

	Density.	Tenacity.	No. of fires endured.
Cast and proved in 1851.	7.287	37811	72
Cast in 1846, and proved	7.247	29423	2582
in 1852.	7.220	22989	800

The form, dimensions, weight, method of casting and cooling, and the manner of proving were the same in all. It will be seen that the gun made of the strongest iron, with a short interval of time between its manufacture and proof, endured the smallest number of fires; and that those made of weaker iron, but proved long after they were cast, endured the greatest number of fires. This remarkable feature in these trials, suggests an inquiry as to the cause of such anomalous results.

The following table exhibits an account of all the experiments made in

casting guns solid and hollow, in pairs, and of the mechanical tests, and the endurance of each in extreme proof. Also, of the extreme proof of other guns of the same model, not cast for experiment.

Extreme Proof and Endurance of Cannon.

Date of proof.	Cannon proved.	Interval between casting and proving.	TEST OF GUN-HEAD SAMPLES.		NUMBER OF FIRES ENDURED.				
					SERVICE CHARGES IN GUNS CAST,		EXTRA HIGH CHARGES IN GUNS CAST,		
			Density.	Tenacity.	Solid.	Hollow.	Solid.	Hollow.	
1849	8 inch Columbiads	34 days	7.222	27569	84	—	—	—	Not burst.
			7.233	27531	—	250	—	—	
1851	8 inch Columbiads	30 days	7.292	37961	72	—	—	—	
			7.287	37638	—	1500	—	—	
1851	10 inch Columbiads	49 days	7.273	40457	19	—	—	—	
			7.306	41952	—	248	—	—	
1852	32 pdr. cannon	110 days	7.271	33590	1000	—	6	—	
			7.281	34307	—	1000	—	21	
	Mean of tests, and total endurance		7.271	35126	1175	2998	6	21	
1844	{ 8 inch Columbiad	100 days	7.276	26367	731	—	—	—	Not burst.
	{ 10 inch Columbiad	100 days	—	—	600	—	12	—	
1852	{ 8 inch Columbiad	6 years	7.247	29423	2582	—	—	—	
	{ 8 inch Columbiad	6 y'rs, 44 d'ys	7.220	22989	800	—	—	—	

In the former report, made in January last, the character and the effects of the strains, which occur in the cooling of iron when cast in large masses, are stated and discussed. But now, it appears from the results obtained in the trials since made, that there is another question to be considered: that is, the longevity of such strains; or the length of time during which a body will remain under a strain, without a renewal of the straining force.

It is assumed that any casting, or any other solid body will, if constantly strained for a long time, adapt itself, in part at least, to its strained position; and lose its power of voluntary restoration to its original position.

Suppose, for example, that a proof bar of cast iron be strained in the testing machine, until its deflection is about two-thirds or three-fourths of that which it will endure without breaking, or until the deflection nearly reaches the point at which incipient molecular separation occurs, and that the pressure be then removed. It will be found that the bar has acquired

a small measure only of permanent set. But if the pressure is not removed, or if removed, it be again applied, and be continued a long time, it will be found that the bar has acquired a permanent set, nearly equal to its deflection, and that its power of restoring itself to its original position has been almost entirely lost. Its particles, it would seem, have adjusted themselves to their new and constrained position, and become free, or nearly so. It appears that they resist constraint, and retain the power of self-restoration, for a short time only; but if the restraint be long continued, they gradually conform themselves to it, and become passive or acquiescent.

A bar which has thus been made to acquire a large permanent set, it is believed, has lost but a small portion of its power to endure renewed strains. It may be again pressed with a similar force, and acquire an additional deflection and permanent set, nearly or quite equal to that which had before been imparted to it. By repeating this process at long intervals of time, the permanent set of a bar may be extended much beyond the deflection which it was capable of enduring when it was first strained.

Familiar examples of the facility with which bodies conform to constrained positions, may be observed in the hoops of common barrels, whether consisting of wood or of iron. The hoops, when first bent around the barrel, lose but a small part of their power of restoration; but when united at their ends, and driven firmly upon the barrel, they soon lose most of their active power of restoration, become passive, and acquire a permanent set, conforming nearly to the circumference on which they were strained. When they have thus acquired this permanent set, they may be further bent upon smaller circles, until reduced to a curve which if attempted at first would have broken them, while the strength of the hoop will remain unimpaired. If solid bodies do thus relieve themselves from strains produced by the application of an external force, why may not a gun casting relieve itself in like manner, from the strains caused by unequal cooling.

The strain produced in cannon by unequal cooling, as described in the preceding reports, is one of compression on the exterior circumference, and of elongation on the circumference of the bore. It may be likened to the strain which would exist in a hollow cylinder, if the latter be cut through its thickness in one of its elements, and the fissure be afterwards enlarged by a mechanical force acting against the surfaces of the fissure. A strain thus produced, would obviously stretch the interior surface of the cylinder,

and compress its exterior surface. Now if we suppose a strain of this kind to be so far extended, as to approach nearly to the point at which incipient molecular separation occurs, any considerable addition of a central force, of any kind, will evidently produce rupture. This is, I believe, the condition of cannon, when under a strain caused by unequal cooling. And as the force of fired gunpowder acts in the same direction, a few fires, if made soon after casting the cannon, will be sufficient to burst it. But if the same cannon, be allowed a sufficient time between the casting and proving, to free itself from strain, it will endure a number of fires proportioned to the tenacity of the metal from which it is made. What length of time may be required to free a gun from strain, can be ascertained only by experiment; but, it will doubtless be found to be proportioned to the hardness and tenacity of the iron, and to the bulk of the gun. Hard, strong iron contracts most, and consequently is most strained, and will require the longest time to relieve itself.

On this hypothesis, the results obtained in the extreme proofs given in the preceding tables, may be rationally accounted for. If we refer to the 8 inch Columbiads cast solid, we find that the one cast in 1851, and proved in 30 days after it was cast, or say in about three weeks after it had cooled—we find that with a tenacity of 37,811, it endured only 72 fires: while, of the two Columbiads of the same model, cast in 1846 and proved in 1852, more than six years afterwards, one of them, with a tenacity of 22,989, endured 800 fires, and the other, with a tenacity of 29,423, endured 2,582 fires, and remains unbroken.

Results so remarkable cannot be accounted for in any other way that I can conceive, than on the assumed hypothesis before mentioned, viz: that large iron castings, when cooled from the exterior, are unavoidably strained in cooling, and that such strains, if within the limits of incipient rupture, are removed by time, leaving the casting free.

The method of cooling from the interior devised by Lieutenant Rodman, tends to prevent injurious strains in cooling. And if the method be sufficiently extended on this principle, a strain in the opposite direction may be produced. The strain, in this case, would be one of compression on the surface of the bore, and of elongation on the circumference of the gun; and the tendency of such a strain, would be to prolong the endurance of the gun, beyond the proportion of fires due to the tenacity of its metal.

This theory of the effect produced by time, in removing the strains caused by the unequal cooling of iron castings, appears to be so well sustained by the facts exhibited in the experiments cited, and its bearing upon the subject of casting heavy cannon, appears to be so important, that I have thought it my duty to state it, and to submit it to the department.

Respectfully your obedient servant,

W WADE.

This theory of the effect produced by time, in removing the strain caused by the unequal cooling of iron castings, appears to be so well sustained by the facts exhibited in the experiments cited, and its bearing upon the subject of casting heavy cannon, appears to be so important, that I have thought it my duty to state it, and to submit it to the department.

Respectfully your obedient servant,

W. WADSWORTH.

REPORT

STRENGTH AND OTHER PROPERTIES OF METALS.

MANUFACTURE OF BRONZE AND IRON CANNON.

1864.

REPORT

ON THE

STRENGTH AND OTHER PROPERTIES OF METALS,

AND ON THE

MANUFACTURE OF BRONZE AND IRON CANNON.

1854.

REPORT

ON THE

STRENGTH AND OTHER PROPERTIES OF METALS, AND ON THE
MANUFACTURE OF BRONZE AND IRON CANNON.

FORT PITT IRON WORKS, PITTSBURG, *August*, 1854.

COLONEL:

I submit herewith a report of bronze and iron cannon, manufactured at the foundries under my supervision, during the years 1850 and 1851.

Having now withdrawn from the public service, and this being the last report I shall have occasion to make on the manufacture of cannon, I have considered it proper to give, in addition to the usual statements, a record of numerous experiments. The report, therefore, gives a full account of all the methods employed to test the qualities of the metals used, and of such other proceedings or experiments, as might tend to benefit this branch of service, or be useful to those who may in future be engaged in conducting it.

The principal purposes of the experiments were to discover methods by which the mechanical properties of metals could be accurately determined, and to ascertain what processes of treating the metal, would give the most beneficial results.

The report describes the various qualities of metals tested, the different methods of treating them, and the results obtained from each.

Numerous specimens of metal exhibiting peculiarities of texture, which fell under my observation at different times, were tested, although they had no direct connection with gun castings. The results obtained in this desultory manner, were often suggestive of a regular series of experiments, afterwards devised and prosecuted, with a view to determine certain facts in relation to the treatment of the metal.

During the period of making these trials, I was occupied in attending to the manufacture of cannon at three different foundries; West Point, Boston, and Chicopee; and was frequently obliged to travel from one to another, making trial tests at either, as other duties permitted. The results were therefore unavoidably recorded in an irregular and promiscuous manner. I have, however, endeavored to select and group them in classes, so arranged as to exhibit the properties of each grade of metal, separately, and in combination, and also the changes of quality effected by different methods of treatment.

The properties of metals which are most material in the manufacture of cannon are tensile strength, hardness, and specific gravity; and to these qualities more particular attention has been given. Metals possess other properties, such as the capacity to resist transverse, and torsional strains, and to endure crushing or compressive forces. A knowledge of these properties in different metals, is of high importance to the engineer and architect, and will be useful to all who may be engaged in designing public works, or ponderous machinery of any kind. Tests in all these various forms, were therefore made whenever suitable opportunities occurred, and the results are recorded in the report. Among the experiments of this class, there will be found several which are new, and of a character which, so far as I know, have not been given in any published works upon the subject.

Drawings of the testing machine, and of the principal instruments employed in making the tests, have been prepared, and are annexed to the report, with a brief description of the principles on which they are constructed, and of the manner in which they are used. Much attention has been bestowed on the general plan and construction of them. Numerous modifications, suggested by experience, have been made from time to time. The details of the several parts, as represented in their perfected form by the drawings, combine the greatest convenience in use, with the most perfect accuracy in results.

The drawings of the testing machine, given in the report, are reduced from a full set of drawings on a larger scale, contained in nine sheets of *Atlas drawing paper*. The latter give the form and the dimensions of all the parts in detail, and are designed to give all needful information for the construction of other machines. These are separately transmitted.

Among the numerous details inserted in the report, there may be many

which would appear to be trivial or too minute, but, such only are inserted as I believed would be found useful to others, engaged in similar investigations. No facts or suggestions are recorded, but such as would have been very useful to myself when commencing this service, and which would have spared me much laborious research.

The report will exhibit the satisfactory progress which has been made, in improving the quality of iron guns under the present regulations, which provide for the constant presence and supervision of an officer at the foundries during their manufacture, and for testing the iron used in them. It will be seen, that the average qualities of all iron guns cast before the year 1841 when the present system was adopted, contrasted with the average of all those cast in 1851 after the system had been matured, were as follows, viz:—

	Density.	Tenacity.
Cast prior to 1841	7.148	23638
Cast in 1851	7.289	37774

The system of official supervision and of testing the metals used, was not extended to the bronze foundries until 1850. The tests of bronze, recorded in the report, show the results of processes heretofore practised in the manufacture of bronze guns, and, that those processes need improvement. The results obtained from the testings of bronze, and recorded in this division of the report, will serve to show the existing condition of the art of manufacturing bronze guns—which, in our service, is yet in its infancy—and also, what further measures are necessary in order to improve it.

In conclusion, I must express the obligations which are due to the proprietors of all the foundries, where the experiments were made, for their zealous co-operation, and for all needful facilities, which they generously furnished.

Respectfully submitted,

W. WADE.

To COL. H. K. CRAIG, COLONEL OF ORDNANCE.

REPORT

ON THE

MANUFACTURE OF 32 PDR. SEA COAST CANNON, AT THE SOUTH
BOSTON FOUNDRY, 1850—1851.

*Tests of Iron, of 1st Fusion, in Rough Pigs; Cast at the Smelting Furnace in Open
Sand Beds.*

No. 1, Pig Iron. Amenia Furnace.	Mark of samples.	TESTS OF SAMPLES.	
		Density.	Tenacity.
Warm blast. { 	250. 1—Ame.	6.949	11020
	250. 2—Ame.	6.947	11820
	Mean	6.948	11420
	5—Ame.	6.974	12311
	6—Ame.	6.975	11937
	7—Ame.	6.992	14501
	8—Ame.	6.973	13130
	Mean	6.978	12970
	1—P. C.	6.938	10948
	2—P. C.	6.949	14087
Cold blast. { 	3—P. C.	6.944	13553
	4—P. U.	6.977	11126
	4—P. L.	7.030	11502
	Mean	6.967	12243
	5—P. C.	7.110	16004
	6—P. C.	6.971	12358
	7—P. C.	7.131	14059
	Mean	7.071	14140
	Mean of all	—	6.991
	Mean of all	—	12693
No. 2, Pig Iron, 1st fusion, Kent Furnace .	C—C—A.	7.315	24349

Tests of Cold Blast Iron, of 2d and 3d Fusions.

Briggs's Furnace Iron.	HOURS IN FUSION.			Mark of samples.	TESTS OF SAMPLES.	
	2d.	3d.	Total.		Density.	Tenacity.
2d fusion	$\frac{1}{2}$	—	$\frac{1}{2}$	1—B.	7.112	15729
	$1\frac{1}{2}$	—	$1\frac{1}{2}$	2—B.	7.109	14082
	$2\frac{1}{2}$	—	$2\frac{1}{2}$	3—B.	7.158	21995
	$3\frac{1}{2}$	—	$3\frac{1}{2}$	4—B.	7.228	25595
	$4\frac{1}{2}$	—	$4\frac{1}{2}$	5—B.	7.237	27852
3d fusion, same iron remelted	—	0	$4\frac{1}{2}$	7 Briggs	7.253	30607
	—	3	$7\frac{1}{2}$	8 Briggs	7.267	32978
	—	4	$8\frac{1}{2}$	9 Briggs	7.391	34599

All of the above samples were taken from the lower end of large cylinders, 14 inches diameter, and 18 inches high, cast in vertical dry sand moulds.

The iron was made at a new furnace, and the trials were made, as an experiment, to ascertain its fitness for the manufacture of cannon. The table shows the effect produced by remelting, and by long continuance in fusion, and the relation which exists between density and tenacity. It shows a strongly marked improvement of quality, by continuance in fusion and remelting; and, with one anomalous exception, that the quality advances as the time in fusion. It shows, also, that although the eight samples tried differ very widely, in both density and tenacity, they vary in the same order throughout, from the lowest to the highest. On comparing any two of the whole number of samples tried, it will be found that that which is lowest, or highest in density, will have a corresponding value in tenacity also.

Amenia Iron of 1st and 2d Fusions.

	Mark of samples.	TESTS OF SAMPLES.	
		Density.	Tenacity.
Mean of Amenias, No. 1, pig iron, from preceding table	250. a. m. e.	6.948	11420
The same iron remelted, cast after 6 hours, in 2d fusion	9. P. G.	7.172	26310

Manufacture of 32 pdr. Sea Coast Cannon, at the South Boston Foundry, 1850—1851.

CASTINGS.		KIND OF IRON USED				TIME IN			TESTS OF GUN-HEADS; MEAN OF 2 SAMPLES.		INSPECTION.			
Date.	Foundry num- bers.	IN PREPARING FIRST FUSION PIGS BY REMELTING.				IN CASTING GUNS.			Total 2d and 3d fu- sions.	Density.	Tenacity.	Register number.	Weight. Pounds.	
		Time in 2d fusion.		Kent. 1st fu- sion.	Amenia.		Total Pounds.							
		Amenia. 2d fusion.	2d fusion.		3d fusion.									
September 24, 1850	819	10000	H. M.	—	8560	2830.	11390	H. M.	H. M.	7.326	34465	1	7296	
October 19, "	823	10000	2. 30	—	8730	2760	11490	1. 30	2. 00	7.325	33905	2	7307	
" 25, "	824	10000	2. 30	—	8300	3070	11370	2. 30	1. 15	7.339	34278	3	7309	
" 28, "	825	10000	2. 30	—	8860	2530	11390	3. 30	1. 30	7.327	35014	4	7285	
November 1, "	826	10000	2. 30	—	8740	2580	11320	3. 30	1. 30	7.316	35824	5	7293	
" 4, "	827	10000	2. 30	—	8700	2550	11250	3. 30	1. 15	7.317	35766	6	7317	
" 8, "	828	10000	2. 15	—	8900	2460	11360	3. 30	2. 15	7.334	36296	7	7317	
" 13, "	829	10000	2. 15	—	8680	2620	11300	3. 15	1. 30	7.285	32681	8	7298	
" 16, "	830	10000	2. 15	—	8230	3020	11250	2. 30	2. 50	7.303	32564	9	7285	
" 20, "	831	10000	2. 15	—	8550	2950	11500	3. 15	2. 15	7.341	35705	10	7328	
" 23, "	832	10000	2. 15	—	8490	2760	11250	3. 30	1. 15	7.324	35827	11	7301	
" 27, "	833	10000	2. 15	—	8300	2870	11170	3. 15	2. 15	7.322	34728	12	7317	
December 3, "	834	10000	2. 15	—	8440	2950	11390	2. 15	2. 20	7.350	36536	13	7349	
" 6, "	835	10000	2. 15	—	9270	3050	12320	3. 30	3. 00	7.316	37804	14	7313	
" 10, "	836	10000	2. 15	—	8440	3100	11540	3. 15	2. 00	7.331	36165	15	7316	
" 14, "	837	10000	2. 15	—	8440	3040	11480	3. 15	2. 15	7.298	36479	16	7308	
" 18, "	838	10000	2. 15	—	8560	3000	11560	3. 15	1. 15	7.303	35783	17	7311	
" 21, "	839	10000	2. 15	—	8320	3070	11390	3. 15	2. 45	7.326	36313	18	7319	
" 24, "	840	10000	2. 15	—	8340	3220	11560	3. 15	2. 00	7.321	36610	19	7310	
" 28, "	841	10000	2. 15	—	8470	2990	11460	3. 15	1. 45	7.345	34484	20	7343	
January 1, 1851	842	8000	2. 15	—	8540	2970	11510	3. 15	1. 15	7.306	35254	21	7302	
" 4, "	843	8000	2. 15	—	8340	3110	11450	3. 30	1. 45	7.317	33826	22	7322	
" 7, "	844	8000	2. 15	—	8600	2840	11440	3. 15	1. 45	7.297	34238	23	7292	
" 11, "	845	8000	2. 15	—	8630	2880	11510	3. 00	1. 45	7.311	36804	24	7308	
" 14, "	846	8000	2. 15	—	9060	2530	11590	3. 15	2. 00	7.316	35914	25	7310	
" 18, "	847	10000	2. 15	—	9550	2280	11830	3. 00	1. 15	7.286	35056	26	7273	
" 21, "	848	8000	2. 15	—	9740	2210	11950	3. 15	2. 30	7.267	34627	27	7268	
" 25, "	849	8000	2. 15	3000	4000	4850	11850	3. 45	1. 30	7.326	31858	28	7301	
" 29, "	850	8000	2. 15	3000	4800	3990	11790	3. 45	1. 30	7.300	32364	29	7312	
" 31, "	851	8000	2. 15	3000	4900	4100	12000	3. 35	3. 40	7.314	32812	30	7331	
Mean of 1 to 27	—	—	—	—	—	—	—	—	—	7.316	35294	}		7308
" 28 to 30	—	—	—	—	—	—	—	—	—	7.313	32345			
" 1 to 30	—	—	—	—	—	—	—	—	—	—	35000			

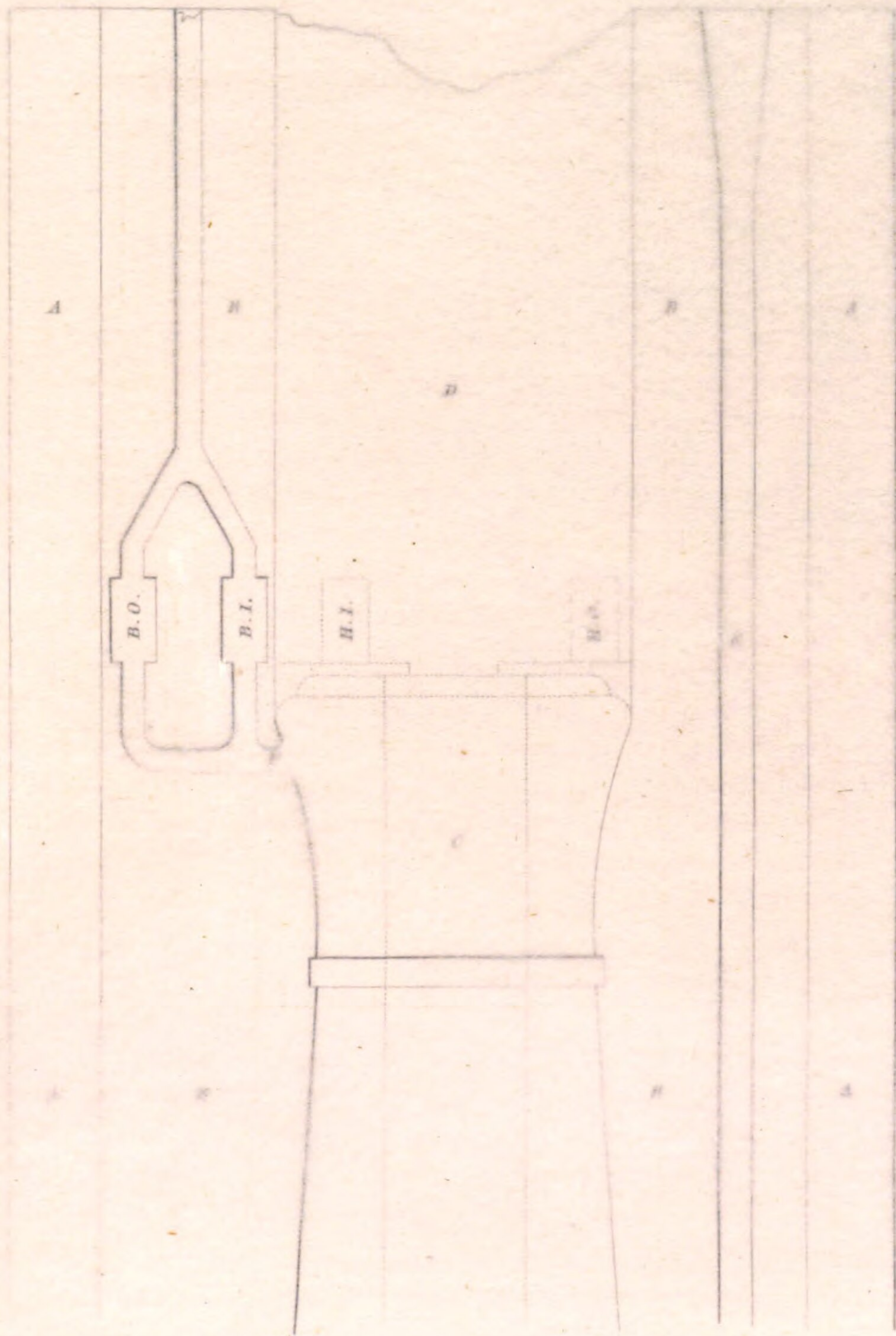
The iron of 2d fusion used in the foregoing castings, consists of remelted pig iron, cast into cylinders, 14 inches diameter and from 18 to 30 inches high. The iron of 3d fusion, consists of gun-heads and of surplus iron from previous gun castings. The gun-heads are cylinders, 16 inches diameter, and 30 inches high. Duplicate samples were taken from each head, and each sample is marked with the foundry number of the gun; and with the letters H. O. when taken from the outside of the head, and with H. I. when taken from the part opposite the surface of the bore. Samples were taken from the cylinders of 2d fusion, used in the guns No. 819 and 833.

In casting gun 833, two small bars were cast in the gun mould, both of which were placed opposite the gun head, at an elevation corresponding with that of the gun head samples. One of them was placed very near the gun head, leaving only a thin partition of sand between them. The other was placed near the outside of the mould, with a small thickness of sand between the bar, and the iron flask. In casting, the liquid iron passes down through a side channel, and enters the mould at the bottom; and then ascends until the mould is filled.

Plate IX. exhibits the upper part of the gun mould, the gun head, the small bars, and the channel through which the iron passes.

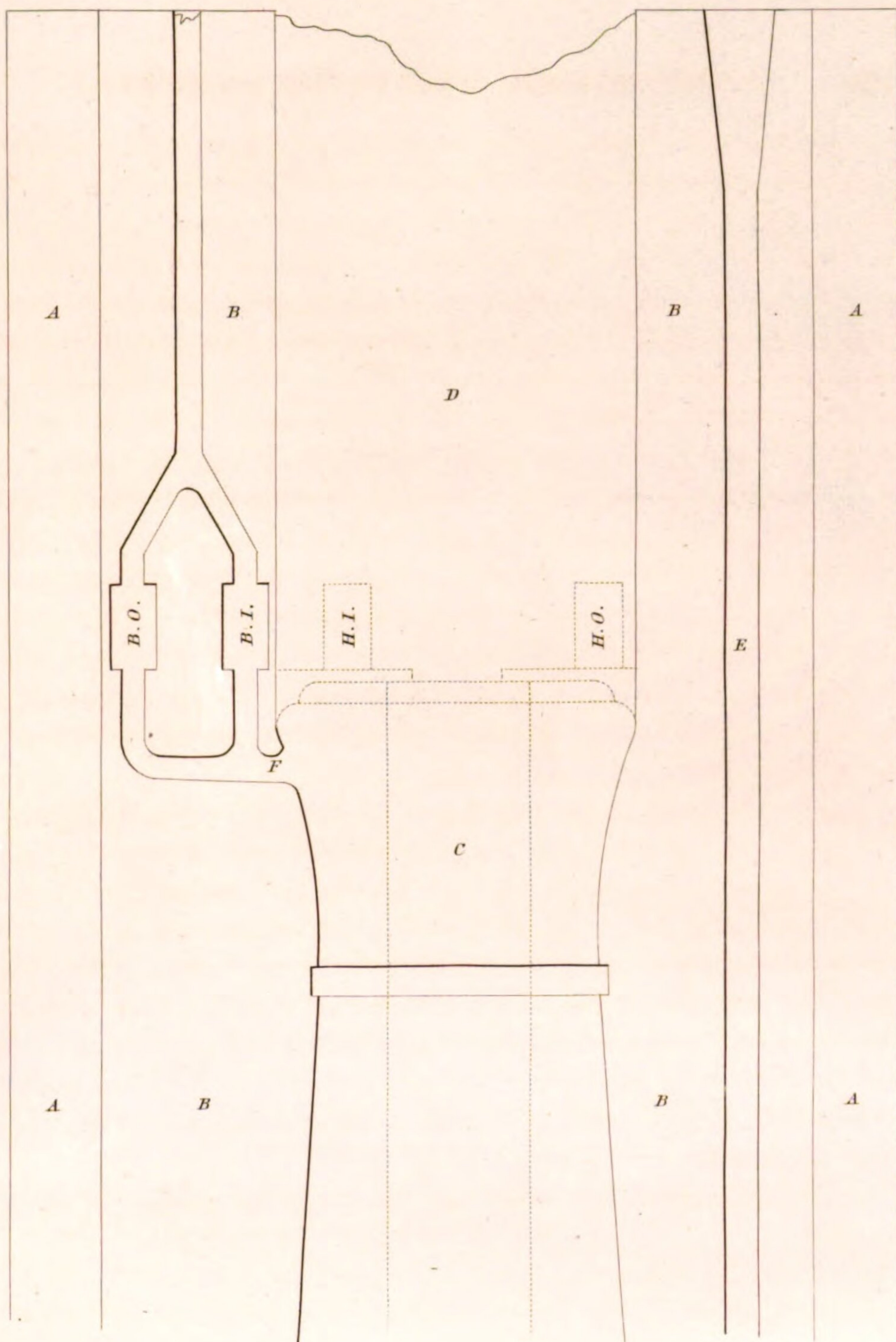
The liquid iron in its ascent, flows into the position occupied by each of the four samples, H. I., H. O., B. I., and B. O. simultaneously, and extends to the same height above each. The quality of the iron in each, at the moment of casting, and when it comes to a state of rest in each position, must therefore be equal. And, as the pressure under which each congeals is the same, any inequalities of density or tenacity, which may be found in the tested samples, can be attributed only to the different circumstances under which they are cooled.

The following table exhibits the results of the testing, of all these samples.



Scale $\frac{1}{8}$.

- A Flanges of the Iron Block.
- B The gun barrel.
- C Upper part of the gun.
- D Gun Head.
- E Channel which conducts the iron to the mould.
- F Channel which conducts the iron from the mould to the small bars B.I. & B.O.
- H.I. & H.O. Position of gun head samples.



Scale $\frac{1}{8}$.

- A Flanges of the Iron Flask.
- B The gun mould.
- C Upper part of the gun.
- D Gun Head.
- E Channel which conducts the iron to the mould.
- F Channel which conducts the iron from the mould to the small bars B.I. & B.O.
- H.I. & H.O. Position of gun head samples.

Iron used in Casting Guns, Nos. 819 and 833.

Description of samples.		Mark of samples.	TESTS OF SAMPLES.	
			Density.	Tenacity.
Iron used in gun 819.	Samples of 2d fusion, taken from cylinders cast at two separate meltings	819—C	7.069	15942
		819—C. 1	7.070	17625
		Mean	7.070	16783
	Same iron remelted, two samples of 3d fusion from one gun head	819. H. I.	7.326	33445
		819. H. O.	7.327	35486
		Mean	7.326	34465
Iron used in gun 833.	Samples of 2d fusion, from cylinders cast at two separate meltings	833. C. 2	7.165	26126
		833. C. 3	7.204	26348
		Mean	7.184	26237
	Same iron remelted, two samples of 3d fusion from one gun head	833. H. I.	7.329	33646
		833. H. O.	7.316	35810
		Mean	7.322	34728
	Same iron, cast at same time, in gun mould; small bars	833. B. I. { Inside bar annealed	7.274	27502
		833. B. O. { Outside bar cooled suddenly	7.386	30163

The effect produced by the different processes of cooling, is shown in the last three results stated in the above table. The quality and condition of the iron, in each of these samples, at the instant when the liquid iron had come to a state of rest in their moulds, must, as before stated, have been exactly equal. But here the equality of condition ceased. The difference in the mass, and in the position of the several moulds, exposed the iron in each to dissimilar influences, which affected the time and manner of their respective congelations and subsequent cooling.

The gun head, being massive, cooled slowly and regularly; and, as the iron, when cast, was in its best condition for strength in so large a mass, the tested samples were high in both density and tenacity.

The small bar, B. O., cast in the gun mould, near the iron flask, at the outside of the mould, congealed in a few moments after casting, and cooled rapidly thereafter. Its position being near the cooling influence of the air, outside of the mould, caused it to cool rapidly; and being distant from the mass of liquid iron in the gun mould, and sheltered from it by a thick wall

of a good non-conducting substance, its cooling was not retarded by the heat in the gun head. The rapid cooling of this bar increased its density from 7.322, in the gun head, to 7.386 in the bar; a difference equal to four pounds in the cubic foot. This increase of density is a consequence which invariably follows the rapid cooling of cast iron. The tenacity of this bar was, however, diminished by rapid cooling. The gun head samples have a tenacity of 34502, and the bar is only 30163; a diminution of 4339 pounds per inch. Such results happen only in cases when the iron is very hard. As a general rule, the tenacity of the common sorts of foundry iron is increased by rapid cooling. In this case, the condition of the iron when cast was *too high*—that is to say, the process of decarbonization had been carried too far—for a maximum strength, when cooled rapidly, in small masses; although it was in its best condition for casting into a large mass, where it must cool slowly.

The other small bar, B. I., cast in the interior of the gun mould, near the gun head, congealed nearly or quite as soon as the bar B. O., and continued to cool down, much below the freezing-point of iron, before its further cooling was met and counteracted by the heat escaping from the liquid iron in the gun head. At this point, the latter increased the temperature of the bar up nearly to the melting point, and thereafter it cooled down very slowly, with the gun head, being all the time excluded from the air, which subjected it to a perfect process of annealation. This process diminished both its density and its tenacity, a result which invariably follows the annealing of cast iron. Its diminished density, as compared with the unannealed bar, is equal to seven pounds per foot; and its diminished tenacity, compared with the gun head, is 7226 pounds per square inch.

The effect produced by remelting iron, and by retaining it in fusion exposed to an intense heat for a long time, is exhibited in the following results, which are extracted from the preceding tables:—

	Density.	Tenacity.
Amenia pig iron, 1st fusion	6.948	11420
Same iron, remelted, 6 hours in 2d fusion	7.172	26310
Another parcel of Amenia iron, prepared for gun No. 833, of 2d fusion	7.184	26237
Same iron, remelted, cast in gun, 3d fusion	7.322	34728

	Density.	Tenacity.
Another parcel of Amenia iron, prepared for gun No. 819, 2d fusion	7.070	16783
Same iron, remelted, cast in gun, 3d fusion	7.326	34465
Briggs's Furnace iron, first casting of 2d fusion	7.112	15729
Same iron, last casting, remelted, after 8 hours, additional, in fusion: 3d fusion . .	7.391	34599

These results show, at a glance, how greatly the quality of iron is modified and improved by remelting and long continuance in fusion. But all kinds of iron are not affected in like manner by these processes. Some kinds of iron were tried, which exhibited favorable indications in the rough pig, of 1st fusion, and were found to be susceptible of a slight improvement only; while, in some other kinds, the tenacity was impaired by remelting. As a general rule, it may be safely assumed, that the No. 1 soft gray pigs, of any make of iron, are more susceptible of improvement by this treatment than the higher grades of iron, made from the same ores, at the same Furnace. The Amenia Furnace iron appears to possess this quality in a very high degree.

	Density.	Tenacity.
The mean results of the 14 pigs of this iron of 1st fusion, are	6.991	12693
And of the 27 guns, made from this iron exclusively, the mean of the gun heads is	7.316	35294

The difference between the iron, as it exists when presented for use, and, as it exists in the body of the finished gun, is, in density, more than 20 pounds per cubic foot, and, in tenacity, as 100 to 278.

Iron made at Kent Furnace was tried, and the pigs of 1st fusion gave very high results, viz: density 7.315, equal to the Amenia of 3d fusion and its tenacity was 24,349, nearly double that of Amenia pigs. In the last three guns cast one part of this iron was mixed with four parts of Amenia, and the mean tenacity of these gun heads was reduced from 35,294, the mean of the 27 previous guns made of Amenia iron exclusively, to 32,345. This experiment serves to show, how unreliable the tests of 1st fusion pig iron are, as means for determining the quality of iron and its suitableness for making cannon.

REPORT

ON THE

MANUFACTURE OF 32 PDR. SEA COAST CANNON, AT WEST POINT FOUNDRY, 1851.

CASTINGS.			KIND OF IRON USED								TESTS OF SAMPLES.				Register number of guns.
Date.	Description.	Foundry number.	IN PREPARING FIRST FUSION PIGS BY REMELTING. GREENWOOD IRON.				IN CASTING GUNS.			PROOF BARS.	GUN-HEADS, MEAN OF TWO SAMPLES.				
			No. 1.	No. 2.	No. 3.	Total.	1st fusion.	2d fusion.	Total.		Density.	Tenacity.	Density.	Tenacity.	
1851			Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	H. M.					
January 13	32 pdr. cannon	416	55	55	—	110	5	87	92	4. 35	7.272	40897	7.228	32481	45
" 17	"	417	42	42	28	112	—	94	94	4. 20	7.340	27626	7.246	37464	46
" 21	"	420	42	42	28	112	—	94	94	4. 25	7.346	31589	7.268	38295	47
March 8	"	427	42	42	28	112	—	94	94	3. 30	7.356	32697	7.260	38197	48
" 11	"	428	42	42	28	112	—	95	95	3. 50	7.318	37920	7.264	38467	49
										Mean	7.326	34146	7.253	36981	

In casting these guns, the experiments which had been commenced in 1850, in the same lot of guns, were resumed and completed. Of the 25 guns cast in 1850, 23 were made in the usual manner, by mixing the different grades of Greenwood iron, known as numbers 1, 2, and 3, and chiefly of 1st fusion. The tests of the gun-head samples from these 23 guns, gave a mean density of 7.252, and a mean tenacity of 31,678. The two other guns cast in 1850, were made from the same kind of iron, prepared for the experiment by remelting. By reference to the report of August 21st, 1850, it will be seen that the experiment was very successful, in improving the quality of the iron.

The five guns reported in this statement, were made of the same kind of Greenwood iron, and, by varying the proportions of the different grades of numbers 1, 2, and 3, and by remelting them, the mean tenacity of the gun head samples, has been increased from 31,671 in 1850, to 36,981 in 1851. And the founders may with the same quality of iron, continue to make any number of guns of the same high tenacity, without any risk of failure.

The details of the numerous experiments made, in arranging the proportions of the different kinds of iron, used in making these guns, are exhibited in the statements which follow:—

Test of Greenwood Iron, First Fusion.

Grades of iron tested. All cast at the Smelting furnace.		Mark of samples.	TESTS OF SAMPLES.	
			Density.	Tenacity.
No. 1 Iron.	{ Rough pigs { Moulded vertical bar	1—P—23	6.974	14000
		1—P—24	7.035	14963
		17—B—1	7.085	16424
		Mean	7.032	15129
No. 2 Iron.	{ Rough pigs {	2. P. 25	7.220	33905
		2. P. 26	7.086	20404
		Mean	7.153	27153
No. 3 Iron.	{ Rough pigs { Moulded vertical bars	3. P. 27	7.244	34737
		3. P. 28	7.247	34112
		18. B. 1	7.235	34882
		19. B. 1	7.193	35961
		Mean	7.230	34923

No. 1. Is the softest gray iron,

No. 2. Is an intermediate, and

No. 3. Is the hardest gray iron; and all are classed as *foundry* iron.

The samples marked P. are taken from the rough pigs, cast in open sand beds, as is customary at smelting furnaces. The samples marked B. are from bars 2 inches square, and 23 inches long, cast in vertical dry sand moulds, as is usual with foundry *proof bars*, but from the same iron, of 1st fusion, as the rough pigs.

In the columns of the following table, headed *Mark of Samples*, the letter B. on any sample, denotes that it is taken from a *proof bar*, and the figures which follow the letter, indicate the fusion, or, the number of times the iron had been melted.

All samples taken from any gun casting, whether from the gun-head, the proof bar, or other casting from the same melting, bear the foundry number of the gun. The letter H. added to the number, denotes that the sample is taken from the *gun head*. The letter O. added to the H. denotes a duplicate sample from the same gun head, at, or near to its exterior surface. The letter H. alone, indicates a sample taken from the interior of the head, near the surface of the bore.

Experimental Trials in Remelting different Grades of Greenwood Iron. West Point Foundry, 1851.

IN PREPARING IRON FOR GUNS.										GUN CASTINGS FROM THE SAME IRON REMELTED.									
Date of casting.	KIND OF IRON USED.				TEST OF SAMPLES, 2D FUSION, PREPARED IRON.			Date of casting.	KIND OF IRON USED.				Time in fusion. H. M.	Guns cast.	Mark of samples. 3d fusion.	TESTS OF SAMPLES.			
	Greenwood. 1st fusion.		Total. Cwt.	Time in 2d fusion. H. M.	Mark of samples. 2d fusion.	Density.	Tenacity.		Greenwood. 1st fusion.	Greenwood. 2d fusion.	Total. Cwt.								
	No. 1.	No. 2.										No. 3.							
1850								1850											
Dec. 14	50	—	—	50	2. 45	1. B.	27.091	20222	Dec. 19	—	{ 42 cwt. remelted } { of Dec. 14 and } { 16, each }	84	3. 00	{ 32 pdr. Navy gun, No. 402; rejected, the iron too soft }	402. B. 402. H. 402. H. O.	7.167 7.093 7.088	29985 25163 26269		
Dec. 23	50	—	—	50	2. 15	3. B.	27.085	24183	Dec. 31	{ 2 cwt. of No. 2 } { 22 cwt. of No. 3 }	{ 48 cwt. of Dec. 23 } { 11 cwt. of Dec. 14 and 16 }	83	2. 30	{ 32 pdr. Navy gun, No. 412 }	412. B. 412. H. 412. H. O.	7.259 7.179 7.159	36916 27544 30276		
1851									1851										
Jan. 4	50	—	—	50	2. 35	4. B.	27.082	20373	Jan. 6	{ 1 cwt. No. 2 } { 34½ cwt. No. 3 }	47½ cwt. of Jan. 4	83	2. 15	{ 32 pdr. Navy gun, No. 413 }	413. B. 413. H. 413. H. O.	7.270 7.224 7.218	39373 28037 31465		
Jan. 8	27½	27½	—	55	2. 15	6. B.	27.189	30276	Jan. 13	5 cwt. No. 3	{ 87 cwt. of Jan. 8 } { and 10 }	92	2. 20	{ 32 pdr. Army gun, No. 416 }	416. B. 416. H. 416. H. O.	7.272 7.228 7.228	40897 32446 32396		
Jan. 14	21	21	14	56	3. 05	9. B.	27.224	37519	Jan. 17	—	All of Jan. 14 and 16	94	2. 00	{ 32 pdr. Army gun, No. 417 }	417. B. 417. H. 417. H. O.	7.340 7.244 7.249	27626 38542 36387		
Jan. 18	21	21	14	56	2. 30	11. B.	27.272	38585	Jan. 21	—	All of Jan. 18 and 20	94	2. 10	{ 32 pdr. Army gun, No. 420 }	420. B. 420. H. 420. H. O.	7.346 7.267 7.270	31589 38426 38164		
Jan. 22	21	21	14	56	1. 20	13. B.	27.246	39553	Mar. 8	—	{ 89 cwt. of Jan. 22 and 23 } { 5 cwt. of Jan. 25 }	94	2. 00	{ 32 pdr. Army gun, No. 427 }	427. B. 427. H. 427. H. O.	7.356 7.256 7.265	32697 Defective 38197		
Jan. 23	21	21	14	56	1. 35	14. B.	27.249	36068	Mar. 11	—	{ 92 cwt. of Jan. 22, 23, and 24 } { 3 cwt. of Jan. 25 }	95	2. 00	{ 32 pdr. Army gun, No. 428 }	428. B. 428. H. 428. H. O.	7.318 7.262 7.267	37920 37382 39553		

Tests of No. 1 Iron, of 2d, 3d, and 4th Fusions; all of the same Iron Remelted.

Date.	Kind of iron used.	Mark of samples.	TEST OF SAMPLES.	
			Density.	Tenacity.
1851				
Jan. 25	Greenwood, No. 1; pigs of 1st fusion	15. B. 2	7.090	20900
Mar. 12	Same iron, remelted	16. B. 3	7.229	30229
" 25	Same iron, again remelted	434. B.	7.301	35786
	Cast into two 12 pdr. ship guns, Nos. 433 and 434	433. H.	7.257	33724
		433. H. O.	7.257	34550
		434. H.	7.258	36699
		434. H. O.	7.256	30287
	Mean of 4 gun-head samples	—	7.257	33815

The iron in these guns, although of 4th fusion, was still of a medium soft gray, and would no doubt have been further improved by another melting; which would have made its 5th fusion.

Statement of the Preceding Trials, arranged in Classes, in the order of the different Grades of Iron, Nos. 1, 2, and 3, and of the number of times melted.

Grades of Greenwood Iron tested.	PROOF BARS.				GUN HEADS.			
	Of what fusion.	Mark of samples.	TEST OF SAMPLES.		Of what fusion.	Mark of samples.	TEST OF SAMPLES.	
			Density.	Tenacity.			Density.	Tenacity.
No. 1 Iron	2d.	1. B. 2	7.091	20222	3d.	402. H.	7.093	25163
		2. B. 2	7.051	18922		402. H. O.	7.088	26269
		3. B. 2	7.085	24183		Mean	7.090	25716
		4. B. 2	7.082	20373				
		5. B. 2	7.116	23463				
		15. B. 2	7.090	20900				
		Mean	7.086	21344	4th.	433. H.	7.257	33724
	3d.	16. B. 3	7.229	30229		433. H. O.	7.257	34550
		402. B.	7.167	29985		434. H.	7.258	36699
		Mean	7.198	30107		434. H. O.	7.256	30287
10 parts of No. 1, of 3d. fusion, and 4 parts, No. 3, of 2d. fusion	4th.	434. B.	7.301	35786	2d. and 3d.	Mean	7.257	33815
	2d. and 3d.	412. B.	7.259	36916		412. H. & O.	7.169	28910
		413. B.	7.270	39373		413. H. & O.	7.221	29751
		Mean	7.195	29330		Mean	7.195	29330
Equal parts of Nos. 1 and 2 mixed	2d.	6. B. 2	7.189	30276	3d.	416. H.	7.228	32446
		8. B. 2	7.150	24900		416. H. O.	7.228	32396
		Mean	7.170	27588		Mean	7.228	32421
	3d.	416. B.	7.272	40897	3d.			
Mixed { 3 parts of No. 1 3 parts of No. 2 2 parts of No. 3	2d.	9. B. 2	7.224	37519		417. H.	7.244	38542
		10. B. 2	7.250	35835		417. H. O.	7.249	36387
		11. B. 2	7.272	38585		420. H.	7.267	38426
		12. B. 2	7.265	39177		420. H. O.	7.270	38164
		13. B. 2	7.246	39553		427. H.	7.256	Defective
		14. B. 2	7.249	36068		427. H. O.	7.265	38197
		Mean	7.251	37789		428. H.	7.262	37382
	3d.	417. B.	7.340	27626		428. H. O.	7.267	39553
		420. B.	7.346	31589		Mean	7.260	38093
		427. B.	7.356	32697				
		428. B.	7.318	37920				
		Mean	7.340	32458				

Summary of the Preceding Mean Results.

Grades of Greenwood Iron tested.	No of fusion.	TEST OF SAMPLES.			
		PROOF BARS.		GUN HEADS.	
		Density.	Tenacity.	Density.	Tenacity.
No. 1	1st.	7.032	15129	—	—
No. 2	1st.	7.153	27153	—	—
No. 3	1st.	7.230	34923	—	—
No. 1	1st.	7.032	15129	—	—
	2d.	7.086	21344	—	—
	3d.	7.198	30107	7.090	25716
	4th.	7.301	35786	7.257	33815
No. 1, of 3d. fusion	2d. and 3d. {	7.259	36916	7.169	28910
No. 3, of 2d. fusion		7.270	39373	7.221	29751
Nos. 1 and 2 mixed	2d.	7.170	27588	—	—
	3d.	7.272	40897	7.228	32421
Nos. 1, 2, and 3 mixed	2d.	7.251	37789	—	—
	3d.	7.340	32485	7.260	38093

The foregoing statements exhibit the qualities of the several grades of the numbers 1, 2 and 3 iron, made at the same furnace, from the same ores; and they show how each are modified, by different fusions at the foundries.

In the No. 1, which is the lowest grade of soft gray iron, the mean of numerous trials is, in the proof bar samples of first fusion, a density of 7.032 and a tenacity of 15,129. The same iron, identically, after being three times remelted, gives in the same sort of proof bar samples of fourth fusion, a density of 7.301, and a tenacity of 35,786; being an increase of density equal to about 17 pounds in the cubic foot, and an increase of tenacity, in the ratio of 100 to 236. This change in these qualities of iron, is effected solely by remelting, and exposure to heat while in fusion. A similar change appears in the gun head samples, made from the same iron, at the 3d. and 4th. fusions.

The above refers to the No. 1 grade of iron exclusively. And it will be seen by the foregoing tables, that the different grades, 1, 2, and 3, vary very materially in quality, in the original pigs of 1st. fusion. By adding to the No. 1 of 3d. fusion, a portion of No. 3 of 2d. fusion, a considerable improvement is made; and by uniting No. 1 and 2, in equal parts, both of 3d. fusion,

still better results are obtained, in both proof bars and gun heads. But when Nos. 1, 2 and 3 are united in 3d. fusion, the highest point of strength in gun heads, is attained, viz: 38,000, which is the mean of the last four guns cast, all of which are of this composition.

The softest kinds of iron, will endure a greater number of meltings with advantage, than the higher grades. The maximum tenacity of proof bars, is attained, in the No. 1 iron, at the 4th. fusion; in the Nos. 1 and 2, mixed, at the 3d. fusion; and in the Nos. 1, 2, and 3, mixed, at the 2d. fusion. At the 3d. fusion of the latter composition, the tenacity of the proof bars diminished, and, at the same time, it increased in the gun heads.

It appears, that when iron is in its best condition for casting into proof bars of small bulk, it is then in a state which requires an additional fusion, to bring it up to its best condition for casting into the massive bulk of cannon. This is distinctly shown in the castings, composed of the Nos. 1, 2, and 3, iron mixed, as seen in guns numbered 417, 420, 427, and 428. In the other compositions, of lower grades of iron, the guns were cast at the same meltings which gave the highest tenacity in the proof bars. And in these cases, the gun heads were of comparatively low tenacity.

The mixtures of Nos. 1 and 3, in 2d. and 3d. fusion; and of 1 and 2, in 3d. fusion, are examples of this. And from the low densities of the gun heads in these cases, there is good reason to suppose that an additional fusion of this iron, would have augmented the tenacity of the gun heads, while it would have diminished that of the proof bars. It may therefore be assumed as a rule not liable to material error, with this Greenwood iron, at least, that the strength of proof bars, at any fusion, may be taken as an approximate measure of the strength of gun heads, made of the same iron, at the next fusion. In selecting, and preparing iron for cannon, we may therefore proceed, by repeated fusions, or by varying the proportions of the different grades, until the maximum tenacity in proof bars is attained, the iron will then be in its best condition for being again melted and cast into cannon.

It will be seen, that the density of the several grades of iron, Nos. 1, 2, and 3, is in the order of their respective numbers, and that all kinds increase at each additional fusion; and also, that the density is greater when cast into small proof bars, which cool quickly, than when cast into large masses, which cool slowly. It appears, also, that the tenacity increases, quite uniformly, with the density, until the latter ascends to some given point; after which,

an increased density is accompanied by a diminished tenacity. The turning point of density, at which this Greenwood iron attains its maximum tenacity, appears to be about 7.27. At this point of density, or near it, whether in proof bars, or in gun heads, the tenacity is greatest. No example of density between 7.272 and 7.301, occurs in the foregoing tables; but, in every instance, where the latter or any higher density is exhibited, it is accompanied by a diminished tenacity.

The assumed point of highest density for maximum strength, 7.27, was nearly, but not quite reached in any of the gun heads. The density was, however, extended as high as it could be safely carried without endangering the soundness of the castings. As the density of the iron is increased, its liquidity when melted is diminished. This causes it to congeal quickly, and to form cavities in the interior of the casting. In the three guns last cast, Nos. 420, 427, and 428, the iron was carried up to its highest limit in this respect. Cavities appeared in the gun heads, and in such parts of the muzzle and bore, as nearly proved fatal to the castings.

If in preparing the iron for these guns, it had been carried higher, either by longer continuance in fusion, or by using a large portion of the No. 3 iron, the castings would have been lost. In the practical treatment of iron in fusion, while preparing it for casting into cannon, we may safely continue it in fusion, with increasing improvement of its quality, so long as sufficient liquidity is retained to insure an exemption from cavities in the interior of the casting. The point at which such cavities of a fatal character will form, will be reached before the point of density for maximum tenacity is arrived at.

A convenient method for determining the condition of the iron while in fusion, and whether it has arrived at the proper condition for casting, or should be longer continued in fusion, is found, in dipping from the melted pool of iron and casting into small bars;—10 inches long, $1\frac{1}{2}$ inches square at one end, and tapering to a point at the other end. The first one is taken from the furnace, and cast, soon after the iron is all melted, and others are cast at such intervals afterwards, as may be judged proper. They are cast vertically, point downwards, in green sand moulds, and cooled rapidly. They are then broken in different places, and the condition of the iron is judged by the appearance of the several fractures. These fractures will exhibit various aspects, from white at the small end, to dark gray at the large end;

and the bars cast at the later periods of the fusion, will exhibit the white at a greater distance from the small end, and the mottle, bright, and lighter shades, will be found advancing towards the large end. This method, although much less reliable than that of an actual measure of density and strength, is convenient, because of its ready application, at short intervals, while the iron is in fusion; and a practised eye will soon be able to mark the progress of the changing quality of the iron, and to determine the proper time for casting the gun.

The extremes of density and tenacity exhibited in the foregoing statement, will be found in the samples, marked 1—P—23, and 416—B. The former has a density of 6.974, and a tenacity of 14,000; and the latter a density of 7.272, and a tenacity of 40,897. This difference of density, is equal to about 19 pounds per cubic foot, and the difference of strength is as 100 to 292, or as one to three nearly.

This extreme difference in these important qualities of iron, made at the same smelting furnace, from the same ores, is produced by the combination and treatment of the iron at the foundry. And it shows the importance of investigating the laws, which prevail in the melting, casting, and cooling of the iron. These laws are now so far satisfactorily ascertained, in reference to this Greenwood iron, that the resulting density and strength which will follow any given course of treatment, may be predicted beforehand with much certainty. Or, such a course of treatment may be devised, as will produce any given degree of density and strength, within the extreme capacity of the material.

Iron made from other ores at other furnaces, may not be governed by the same laws under similar treatment, and may not be susceptible of improvement under any treatment; but, whatever may be the make or character of any iron, the laws which do govern in the melting, casting, and cooling of it, may be readily ascertained by means of the testing machine, as now perfected, after a few trials judiciously varied. Such trials may be made, without incurring the expense and risk of casting cannon for this purpose.

Proof bars, and, when necessary, large masses resembling gun heads, may be cast from the ordinary meltings of the foundry, made for other castings. Results obtained in this manner, will be a safe guide in determining the character of the iron, and what may be expected from it, when similarly treated and cast into cannon.

The effects produced by the several methods of treating the iron, as described in the foregoing pages, are not to be regarded as the accidental results of mere chance combinations. They are founded on certain laws, which the experiments detailed have developed and established, and which may be successfully applied in all castings of cannon.

After the completion of the castings, and tests, at the West Point Foundry in March 1851, four large Columbiads were cast at the Fort Pitt Foundry, in July and August of the same year. These were two 8 inch, and two 10 inch Columbiads, made for the purpose of an extreme proof with powder and balls. They were made from the same qualities of Greenwood iron, and, although made at a foundry five hundred miles distant, and by founders not before acquainted with the qualities of this iron, or with its proper treatment, yet by following the laws which had been developed in the trials at West Point and Boston Foundries, the same and even better results were obtained.

The tests, of the samples taken from the heads of these four Columbiads, which are extracted from the report of the trial of them dated January 24th, 1852, are as follows:—

Fort Pitt Foundry, 1851.

Cannon tested.	Mark of samples.	Density.	Tenacity.
Two 8 inch Columbiads	3. H. O.	7.289	36891
	3. H. I.	7.295	39031
	4. H. O.	7.281	43650
	4. H. I.	7.290	36090
Two 10 inch Columbiads	5. H. O.	7.273	40457
	6. H. O.	7.296	40997
	6. H. I.	7.306	42425
	Mean	7.290	39934
Four 32 pdr. guns, the last cast at West Point Foundry	Mean	7.260	38093

These results, obtained at different foundries, show what may be accomplished anywhere, with good materials, skilfully treated, according to laws now known and established. The trials at West Point Foundry, appeared to indicate that a density of 7.27 was the proper point for a maximum strength of the Greenwood iron, but by the results afterwards obtained at the Fort Pitt Foundry, which are stated in the above table, it appears that a higher density is better. The highest tenacity obtained in any case, was

given by samples taken from the 10 inch Columbiad No. 6, after it was broken by an extreme proof. Duplicate samples were taken from the same part of a fragment of the chase, near the neck; the tenacity of one of them was 44,917, and of the other 45,970, and the density of each was 7.304.

While attending to the casting, testing, and inspection of the cannon at West Point Foundry, I was occupied in devising and constructing at the same foundry an improved testing machine, designed for use at the Pikesville Arsenal. And for the purpose of verifying its adjustments, and of adapting it to the various forms of testing metals then contemplated, duplicate samples were provided of the same kinds of iron, as were used in the preceding tests. These samples were tested, by transverse, and torsional strains, and by compressing, and indenting forces. A few samples were also tried by an internal force, applied to bursting hollow cylinders.

The following tables exhibit the results of these trials:—

Transverse Strength of Cast Iron. West Point Foundry, 1851.

KIND OF IRON.		Mark of samples.	DIMENSIONS OF BARS.			DEFLECTION AND SET UNDER PRESSURE OF						Break- ing weight. Pounds.	Transverse strength. $S = \frac{l w}{4 b d^2}$ value of S.		
Greenwood.	Of what fusion.		Breadth.	Depth.	B D ² .	5000 LBS.		10000 LBS.		15000 LBS.					
						Deflec- tion.	Set.	Deflec- tion.	Set.	Deflec- tion.	Set.				
Grade No. 1 Grade No. 2 Grade No. 3	1st. {	No. 17	2.095	2.081	9.074	.033	.002	—	—	—	—	9600	5290		
		No. 18	2.080	2.068	8.897	.028	.003	.073	.007	.130	.027	15500	8725		
		No. 21	2.196	2.101	9.698	.008	.000	.035	.000	.080	.005	15300	7888		
Grade No. 1	2d. {	1. B. 2	2.025	2.047	8.489	—	—	.092	.000	—	—	10500	6185		
		2. B. 2	1.982	2.037	8.224	—	—	—	—	—	—	9500	5776		
		5. B. 2	1.984	2.010	8.013	.035	.003	.110	.015	—	—	10300	6437		
		15. B. 2	1.988	2.037	8.249	.032	.002	—	—	—	—	9800	5940		
		Mean	—	—	8.244	.033	.002	.101	.007	—	—	—	6084		
	3d. {	16. B. 3	1.985	2.002	7.955	.034	.001	.091	.009	—	—	12500	7857		
		402. B.	2.064	2.035	8.546	.058	.019	.122	.024	—	—	11600	6787		
Grade No. 1	4th.	Mean	—	—	8.250	.046	.010	.106	.016	—	—	—	7322		
		434. B.	1.991	2.043	8.309	.037	.003	.077	.008	.127	.018	15700	9488		
		412. B.	1.998	1.970	7.753	.031	.000	.086	.008	—	—	15500	9996		
10 parts No. 1, and 4 parts No. 3	2d. and 3d. {	413. B.	1.948	2.005	7.830	.041	.010	.081	.012	—	—	14900	9515		
8 parts No. 1, and 6 parts No. 3	2d. and 3d. {	6. B. 2 8. B. 2 Mean	1.982 1.981 —	1.990 2.012 —	7.848 8.018 7.933	.050 .050 .050	.000 .000 .000	.140 .102 .121	.000 .015 .007	— — —	— — —	12000 11600 7440	7646 7234		
Equal parts of Nos. 1 and 2 mixed	2d. {		3d.	416. B.	1.971	1.991	7.816	.040	.000	.085	.012	—	—	14400	9212
				2d. {	9. B. 2	1.988	2.049	8.351	.025	.000	.070	.000	—	—	14500
		10. B. 2			2.004	1.974	7.812	.025	.000	.075	.005	—	—	13700	8768
	11. B. 2	2.015	1.979		7.892	.045	—	.082	.015	—	—	12900	8173		
	12. B. 2	1.984	2.016		8.066	.015	.000	.065	.000	.125	.005	15700	9732		
	13. B. 2	2.019	1.993		8.021	.015	.000	.061	.000	—	—	13800	8603		
	Mean	—	—	8.028	.027	.000	.071	.004	—	—	—	8792			
3d. {	417. B.	2.001	1.963	7.710	.030	.003	.100	.007	—	—	13900	9014			
	420. B.	1.975	1.990	7.820	.039	.004	.077	.009	.149	.023	15200	9719			
	427. B.	1.968	1.993	7.821	.043	.004	.088	.013	—	—	15000	9590			
	428. B.	2.020	1.943	7.625	.042	.003	.085	.008	—	—	13300	8722			
	Mean	—	—	7.744	.038	.003	.087	.009	—	—	—	9011			

Summary of Preceding Mean Results.

Grade of iron.	Of what fusion.	<i>B D</i> ² .	DEFLECTION AND SET UNDER PRESSURES OF						Transverse strength. Value of <i>S</i> .
			5000 LBS.		10000 LBS.		15000 LBS.		
			Deflection.	Set.	Deflection.	Set.	Deflection.	Set.	
No. 1	1st.	9.074	.033	.002	—	—	—	—	5290
	2d.	8.244	.033	.002	.101	.007	—	—	6084
	3d.	8.250	.046	.010	.106	.016	—	—	7322
	4th.	8.309	.037	.003	.077	.008	.127	.018	9448
Nos. 1 and 3	2d. and 3d.	7.791	.036	.005	.084	.010	—	—	9755
Nos. 1 and 2	2d.	7.933	.050	.000	.121	.015	—	—	7440
	3d.	7.816	.040	.000	.085	.012	—	—	9212
Nos. 1, 2, and 3	2d.	8.028	.027	.000	.071	.004	.125	.005	8792
	3d.	7.744	.038	.003	.087	.009	.149	.023	9011

By these results, it appears that the transverse strength of iron is greatly improved by remelting. In the trials of the No. 1 iron, the strength is nearly doubled in passing from the first to the fourth fusion. In the mixed iron of Nos. 1, 2, and 3, the trials include the second and third fusions only; and in these, the increased strength by remelting, is equally constant, although in a less degree.

The different grades of iron do not exhibit any marked difference in deflection, and permanent set, under the same pressures. But these determinations are less accurate than those for transverse strength, as the results recorded are not reduced to bars of uniform dimensions; and, although the bars were all moulded from the same patterns, the breadth and depth of the bars varied considerably. Those cast from the soft iron, of lower grades, contracting less in cooling, have a larger cross section than those cast from the higher grades of iron, which contract more in cooling.

The differences, in this respect, are shown, in figures, in the column under the head of $B D^2$.

All of the bars, when tested, were supported at both ends, the load being applied in the middle; the distance between the supports, being 20 inches.

Torsional Strength of Cast Iron. West Point Foundry, 1851.

GREENWOOD IRON.		ANGLES OF TORSION UNDER DIFFERENT WEIGHTS, APPLIED AT 25 INCHES FROM CENTRE OF BARS.												TORSIONAL STRENGTH, OR VALUE OF $S = \frac{wr}{d^3}$.		FRACTURES.					
Of what grade and mixture.		Mark of bars.	Diameter of bars.	1000 LBS.			1500 LBS.			2000 LBS.			2500 LBS.			Great-est angle.	Break-ing weight.	$S = \frac{wr}{d^3}$.		Diameters long.	Angles from transverse base.
				Deflec-tion.	Set.	Resto-ration.	Deflec-tion.	Set.	Resto-ration.	Deflec-tion.	Set.	Resto-ration.	Deflec-tion.	Set.	Resto-ration.			Ulti-mate. of $\frac{1}{2}^\circ$.	Ratio.		
No. 1 Iron	2d.	1. B. 2	1.915	1° 9	0° 0	1° 9	4° 0	0° 7	3° 3	—	—	—	—	—	13° 7	1920	6835	4984	730	1.462	32° 3
		2. B. 2	1.905	2° 4	0° 3	2° 1	7° 0	3° 0	4° 0	—	—	—	—	—	7° 8	1550	5605	4340	774	1.942	37° 7
		5. B. 2	1.921	1° 6	0° 0	1° 6	5° 5	1° 8	3° 7	—	—	—	—	—	18° 3	1840	6489	4585	706	1.614	32° 3
		15. B. 2	1.922	2° 7	0° 5	2° 2	7° 2	3° 5	3° 7	—	—	—	—	—	12° 0	1640	5775	3861	687	1.639	33° 5
		Mean	1.916	2° 2	0° 2	2° 0	5° 9	2° 2	3° 7	—	—	—	—	—	12° 9	1737	6176	4442	724	1.664	33° 9
10 parts No. 1, and 4 parts No. 3	3d.	16. B. 3	1.875	1° 7	0° 0	1° 7	3° 0	0° 3	2° 7	7° 6	3° 8	3° 8	—	—	16° 0	2320	8799	6447	733	2.000	38° 0
		412. B.	1.921	1° 5	0° 0	1° 5	2° 4	0° 1	2° 3	3° 8	0° 6	3° 2	6° 5	2° 0	4° 5	2870	10153	6722	662	2.084	38° 5
	2d. and 3d.	413. B.	1.906	1° 5	0° 0	1° 5	2° 3	0° 1	2° 2	4° 1	0° 8	3° 3	7° 6	2° 9	4° 7	2590	9351	6500	695	1.967	39° 5
		6. B. 2	1.913	1° 8	0° 0	1° 8	3° 6	0° 7	2° 9	—	—	—	—	—	—	2320	8285	5000	603	1.725	37° 7
	Equal parts Nos. 1 and 2, mixed	2d.	8. B. 2	1.941	2° 0	0° 2	1° 8	4° 1	1° 2	2° 9	11° 6	8° 3	3° 3	—	—	21° 7	2170	7410	4446	600	1.855
Mean			1.927	1° 9	0° 1	1° 8	3° 8	0° 9	2° 9	—	—	—	—	—	—	2245	7847	4723	601	1.790	37° 2
3d.		416. B.	1.893	1° 2	0° 0	1° 2	2° 4	0° 0	2° 4	4° 2	0° 8	3° 4	9° 3	4° 9	4° 4	2840	10467	7000	669	2.055	41° 0
		9. B. 2	1.910	1° 5	0° 1	1° 4	2° 9	0° 2	2° 7	5° 5	1° 9	3° 6	—	—	17° 0	2600	9329	6458	693	2.042	39° 7
3 parts No. 1, 3 parts No. 2, 2 parts No. 3. Mixed		2d.	10. B. 2	1.916	1° 3	0° 0	1° 3	2° 5	0° 0	2° 5	4° 2	0° 6	3° 6	8° 5	3° 8	4° 7	2820	10025	6931	691	1.983
	11. B. 2		1.924	1° 4	0° 0	1° 4	2° 4	0° 1	2° 3	4° 0	0° 6	3° 4	7° 8	3° 3	4° 5	2700	9477	6845	722	2.027	42° 0
	12. B. 2		1.882	1° 3	0° 0	1° 3	2° 4	0° 1	2° 3	4° 2	0° 9	3° 3	9° 4	4° 6	4° 8	2670	10013	6937	693	2.179	43° 7
	Mean		1.908	1° 4	0° 0	1° 4	2° 5	0° 1	2° 4	4° 5	1° 0	3° 5	8° 6	3° 9	4° 7	2697	9711	6793	700	2.058	40° 1
	3d.	417. B.	1.903	1° 7	0° 1	1° 6	2° 7	0° 4	2° 3	4° 2	0° 8	3° 4	—	—	—	7° 0	2490	9033	6892	763	2.190
420. B.		1.879	1° 7	0° 1	1° 6	2° 5	0° 3	2° 2	3° 9	0° 5	3° 4	6° 6	2° 0	4° 6	7° 0	2550	9610	7537	784	2.209	44° 2
427. B.		1.869	1° 4	0° 0	1° 4	2° 4	0° 0	2° 4	4° 0	0° 2	3° 8	—	—	—	6° 5	2420	9254	7812	844	2.140	41° 5
428. B.		1.980	1° 4	0° 1	1° 3	2° 5	0° 2	2° 3	3° 8	0° 6	3° 2	6° 5	3° 0	3° 5	7° 3	2600	8362	6280	751	2.071	40° 0
	Mean	1.908	1° 6	0° 1	1° 5	2° 5	0° 2	2° 3	4° 0	0° 5	3° 5	6° 5	2° 5	4° 0	6° 9	2515	9065	7130	786	2.152	42° 7

Summary of the Preceding Mean Results of the Torsional Strength of Cast Iron.

Kind of Cast Iron tested.	Of what fusion.	Diameter of bars.	ANGLES OF PERMANENT SET UNDER THE DIFFERENT PRESSURES OF					Break- ing weight.	TORSIONAL STRENGTH, OR VALUE OF S.			FRACTURES.	
			10000 lbs.	15000 lbs.	20000 lbs.	25000 lbs.	Greatest angle of deflection.		Ultimate.	At set of $\frac{1}{2}^{\circ}$.	Ratio.	Diameters long.	Angles from transverse base.
No. 1 Iron	{ 2d. 3d.	1.916 1.875	0° 2 0° 0	2° 2 0° 3	— 3° 8	—	12° 9 16° 0	1737 2320	6176 8799	4442 6447	.724 .733	1.664 2.000	33° 9 38° 0
Nos. 1 and 3, mixed	2d. and 3d.	1.913	0° 0	0° 1	0° 7	2° 4	10° 5	2730	9752	6611	.678	2.025	39° 0
Nos. 1 and 2, mixed	{ 2d. 3d.	1.927 1.893	0° 1 0° 0	0° 9 0° 0	— 0° 8	— 4° 9	21° 7 16° 7	2245 2840	7847 10467	4723 7000	.601 .669	1.790 2.055	37° 2 41° 0
Nos. 1, 2, and 3, mixed	{ 2d. 3d.	1.908 1.908	0° 0 0° 1	0° 1 0° 2	1° 0 0° 5	3° 9 2° 5	14° 0 6° 9	2697 2515	9711 9065	6793 7130	.700 .786	2.058 2.152	40° 1 42° 7

Torsional Strength of Wrought Iron and Bronze. West Point and Boston.

Bars tested.	Mark of bars.	Diameter of bars.	ANGLE OF PERMANENT SET UNDER DIFFERENT PRESSURES, OF											Greatest angle of deflection.	Greatest weight applied.	TORSIONAL STRENGTH, OR VALUE OF <i>S</i> .			
			500 bs.	600 lbs.	700 lbs.	800 lbs.	900 bs.	1000 lbs.	1100 lbs.	1200 lbs.	1300 lbs.	1400 lbs.	1500 lbs.			At greatest weight.	At set of $\frac{1}{2}^{\circ}$.	Ratio.	
Wrought Iron Bronze	1	1.891	—	—	—	—	—	—	—	0° 30	1° 31	2° 81	9° 8	16° 1	17° 5	1500	5546	4289	.773
	2	1.908	—	—	—	—	—	—	0° 10	0° 75	3° 55	6° 95	10° 0	15° 4	16° 6	1500	5399	3779	.700
	3	1.902	—	—	—	—	0° 7	1° 20	6° 70	12° 10	18° 61	25° 3	37° 7	39° 7	39° 7	1500	5450	3197	.587
	—	1.895	—	1° 3	2° 7	5° 8	6° 0	27° 3	34° 00	43° 00	53° 5	77° 0	95° 0	98° 0	98° 0	1500	5511	2021	.367

The diameters of the bars tested in these torsional trials, are given in the tables. The distance between the keys, which secure the ends of the bars when strained, is 15 inches. The length of that part of the bar subject to torsion, and in which deflection occurs, is equal to about 8 diameters; and, as the torsional angle of a bar will vary as the length of the bar under an equal pressure, the results, if reduced to an unit of length equal to one diameter, would be only one eighth part of the angles given in the table.

The deflection of the bars was noted at each addition of 100 pounds to the pressure, and at each addition of 500 pounds, the bar was released from strain, and the permanent set ascertained. The force producing a set of half a degree, in each of the different bars, is approximated, by interpolating the nearest pressures. The value of S at the set of $\frac{1}{2}^\circ$ thus determined, is inserted in the table, and the relation which it bears to the ultimate value of S as determined by the breaking weight, is given in an adjoining column. From this it appears, that the force which gives a bar a permanent set of $\frac{1}{2}^\circ$, is about $\frac{7}{10}$ of that which will break it. This proportion is quite uniform in all the bars tested, although they vary in strength, as two to one.

The fracture of these bars has a form peculiar to torsional strains. It exhibits a regular helix, connected at its extremities, by short curves, with a right line which coincides nearly with an element of the cylinder. The length of fracture, and angle of the helix, vary, in some degree, with the quality of the iron,—the strongest bars, giving the longest fractures. The tables include, with the 18 bars of various kinds of cast iron, 3 of wrought iron, and 1 of bronze. The results obtained, show that the capacity of wrought iron to resist torsional deflection, equals cast iron, under strains which do not produce a permanent set. But this set commences under a less force in wrought, than in cast iron, and yields more readily thereafter. The strongest bar of wrought iron tried, acquired a permanent set of half a degree, under a less strain, than the lowest grade of cast iron bars which were tested. The mean values of S which give a set of $\frac{1}{2}^\circ$ in wrought iron, are about $\frac{6}{10}$ of the mean values of S , giving a like set to cast iron.

Some trials were formerly made to determine the relative torsional strength of bars, of different forms, and as the results were not then reported, they are now given in the following Table.

Torsional Strength of Cast Iron Bars, of different Forms

DESIGNED AREAS OF SECTION—		1 SQUARE INCH.			
Form of bars—scale $\frac{1}{8}$ size					
Diameter, or side of squares	{ Exterior	1.000	1.135	1.300	1.4115
	{ Interior	1.005	—	.650	.8390
Length of the part reduced to form		3.000	3.000	3.250	3.6000
Measured areas of section		1.005	1.0118	.99547	1.01194
Weight applied at 25 inches from the axis of the bars; and the angles of torsion produced by each weight, in degrees and decimals		lbs.			
		100	0°.80	0°.15	0°.20
		200	1°.60	0°.55	0°.50
		300	3°.95	2°.00	1°.05
		400	—	6°.00	2°.40
		500	—	—	5°.25
		600	—	—	—
		700	—	—	5°.50
		800	—	—	—
		900	—	—	—
		1000	—	—	—
		1100	—	—	—
		1200	—	—	—
		1300	—	—	—
		1400	—	—	—
		1500	—	—	—
		1600	—	—	—
		1700	—	—	—
		1800	—	—	—
		1900	—	—	—
		2000	—	—	—
		2100	—	—	—
		2200	—	—	—
		2300	—	—	—
		2400	—	—	—
		2500	—	—	—
		2600	—	—	—
		2700	—	—	—
		2800	—	—	—
		2900	—	—	—
		3000	—	—	—
		3100	—	—	—
		3200	—	—	—
		3300	—	—	—
		3400	—	—	—
		3500	—	—	—
		3600	—	—	—
		3700	—	—	—
Last angle		6°.60	8°.00	6°.00	6°.30
Breaking weight, in pounds		350	430	520	625

and of different Dimensions. Fort Pitt Foundry, 1846.

2 SQUARE INCHES.				3 SQUARE INCHES.			
							
1.415	1.595	1.811	2.211	1.750	1.955	2.261	3.250
1.415	—	.906	1.544	1.748	—	1.280	2.605
3.550	3.600	4.600	5.600	6.500	4.800	5.750	8.000
1.9994	1.9981	1.93122	1.9671	3.059	3.0018	2.7283	2.9661
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
1°.10	1°.20	0°.70	0°.40	0°.70	0°.55	0°.50	0°.25
1.40	1.40	0.85	0.50	0.90	0.75	0.55	0.33
1.95	1.70	1.00	0.60	1.20	0.80	0.60	0.40
2.40	2.30	1.30	0.70	1.30	0.90	0.70	0.44
3.25	2.90	1.60	0.75	1.50	1.00	0.77	0.48
—	3.55	1.80	0.92	1.80	1.10	0.85	0.56
—	4.50	2.55	1.00	2.10	1.35	0.90	0.60
—	6.00	3.30	1.25	2.45	1.60	1.00	0.60
—	7.80	4.45	1.40	2.75	1.75	1.10	0.60
—	—	5.85	1.65	3.17	1.95	1.22	0.60
—	—	—	1.95	3.75	2.20	1.36	0.63
—	—	—	2.38	4.30	2.45	1.60	0.70
—	—	—	2.80	5.05	2.95	1.70	0.76
—	—	—	3.30	6.00	3.45	1.95	0.90
—	—	—	4.05	7.05	4.00	2.15	0.95
—	—	—	—	8.40	4.75	2.35	0.95
—	—	—	—	9.85	5.60	2.82	0.97
—	—	—	—	—	6.55	3.12	1.00
—	—	—	—	—	—	3.60	1.00
—	—	—	—	—	—	4.20	1.10
—	—	—	—	—	—	—	1.11
—	—	—	—	—	—	—	1.25
—	—	—	—	—	—	—	1.30
—	—	—	—	—	—	—	1.35
—	—	—	—	—	—	—	1.45
—	—	—	—	—	—	—	1.50
—	—	—	—	—	—	—	1.60
—	—	—	—	—	—	—	1.70
—	—	—	—	—	—	—	1.80
—	—	—	—	—	—	—	1.90
—	—	—	—	—	—	—	2.05
—	—	—	—	—	—	—	2.15
—	—	—	—	—	—	—	2.35
3°.50	8°.70	7°.50	5°.00	10°.60	7°.65	4°.50	2.50
920	1340	1490	1980	2160	2280	2450	3800

Summary of the Preceding Results.

Areas of cross section, nearly,	BREAKING WEIGHT PER SQUARE INCH OF CROSS SECTION.					
	Solid square.	Solid cylinders.	HOLLOW CYLINDERS.			
			Interior diameters, in parts of exterior.	Breaking weight.	Interior diameters, in parts of exterior.	Breaking weight.
1 inch	Pounds. 8706	Pounds. 10649	$\frac{5}{10}$	Pounds. 13059	$\frac{6}{10}$	Pounds. 15441
2 inches	11505	16766	$\frac{5}{10}$	19289	$\frac{7}{10}$	25164
3 inches	17653	18989	$\frac{5}{10}$	22480	$\frac{8}{10}$	32029

By these results it appears, that solid square shafts have about one-fifth less strength than solid cylinders of equal areas; and that hollow cylinders, the interior and exterior diameters of which are as 1 to 2, have about one-fifth more strength than solid cylinders of like areas; and, that the strength of hollow cylinders increases, as the proportion of the interior to the exterior diameter is enlarged.

All of the bars tested were of common foundry iron, of a mean torsional strength of 7725. In order to insure an equality of material in all the samples, four bars were cast in vertical dry sand moulds, poured at the same time, from the same ladle of metal, into the four moulds, which were contained in the same flask. Each bar was of sufficient length to furnish three samples of the same form:—all the solid squares, from one bar; the solid cylinders, from another; the hollow cylinders, with diameters proportioned as 1 to 2, from a third bar; and the remainder, from the fourth bar.

Resistance to Crushing Forces, or the Compressive Strength of Cast Iron. West Point Foundry, 1851.

KIND OF GREENWOOD IRON.		Mark of samples.	DIMENSIONS OF SAMPLES—INCHES.			RESISTANCE; OR THE VARIATIONS IN FORM UNDER THE DIFFERENT PRESSURES OF																								Resistance per square inch $\frac{1}{2}$ area	Breaking weight.	Angle of fracture from the end.
Of what grade.	Of what fusion.		Length.	Diameter.	Ratio $\frac{L}{d}$	10000 LBS.			15000 LBS.			20000 LBS.			25000 LBS.			30000 LBS.			35000 LBS.			40000 LBS.								
			Depres- sion.	Resto- ration.	Set.	Depres- sion.	Resto- ration.	Set.	Depres- sion.	Resto- ration.	Set.	Depres- sion.	Resto- ration.	Set.	Depres- sion.	Resto- ration.	Set.	Depres- sion.	Resto- ration.	Set.	Depres- sion.	Resto- ration.	Set.	Depres- sion.	Resto- ration.	Set.						
No. 1	2d.	1. B. 2	1.507	.605	2.49	—	—	—	.022	.009	.013	.068	.011	.057	.187	.012	.175	—	—	—	—	—	—	—	—	—	—	—	30000	104357	58°.6	
		2. B. 2	1.540	.600	2.57	—	—	—	.031	.010	.021	.074	.008	.066	.181	.012	.169	—	—	—	—	—	—	—	—	—	—	—	23900	84529	50.5	
		5. B. 2	1.503	.603	2.49	—	—	—	.046	.009	.037	.095	.018	.077	—	—	—	—	—	—	—	—	—	—	—	—	—	—	32700	114504	52.7	
		15. B. 2	1.503	.606	2.48	.003	.003	.000	.008	.003	.005	.005	.024	.079	.012	.067	.184	.012	.172	—	—	—	—	—	—	—	—	—	—	27600	95692	46.0
		Mean	1.513	.603	2.51	.003	.003	.000	.008	.003	.005	.003	.024	.079	.012	.067	.184	.012	.172	—	—	—	—	—	—	—	—	—	—	28550	99770	52.0
	3d.	16. B. 3	1.509	.603	2.50	.003	.003	.000	.008	.005	.003	.012	.008	.043	.020	.023	.058	.007	.051	.133	.023	.110	.180	.056	.124	40100	140415	Bent and crumbled				
		402. B.	1.507	.603	2.50	.006	.005	.001	.008	.006	.002	.017	.012	.005	.032	.023	.009	.066	.022	.044	.125	.029	.096	—	—	—	—	—	—	39600	188666	57.7
		Mean	1.508	.603	2.50	.004	.004	.000	.008	.006	.002	.014	.010	.004	.037	.021	.016	.062	.014	.048	.129	.026	.103	.180	.056	.124	39850	139540	57.7			
		412. B.	1.250	.505	2.48	.005	.004	.001	.013	.010	.003	.022	.009	.013	.054	.021	.033	.100	.014	.086	—	—	—	—	—	—	—	—	—	33600	167752	53.5
		413. B.	1.246	.501	2.49	.008	.008	.000	.009	.005	.004	.025	.008	.017	.057	.017	.040	.103	.011	.092	—	—	—	—	—	—	—	—	—	33400	169427	54.0
Equal parts Nos. 1 and 2, mixed	2d.	6. B. 2	1.508	.603	2.50	—	—	—	.006	.004	.002	.017	.009	.008	.036	.007	.029	.076	.014	.062	.146	.011	.135	—	—	—	—	—	—	40100	140415	52.8
		8. B. 2	1.505	.604	2.49	.005	.004	.001	.011	.008	.003	.026	.012	.014	.044	.011	.033	.085	.012	.073	.192	.006	.186	—	—	—	—	—	—	38200	133321	52.7
		Mean	1.506	.603	2.49	.005	.004	.001	.008	.006	.002	.021	.010	.011	.040	.009	.031	.080	.013	.067	.169	.008	.161	—	—	—	—	—	—	39150	136868	52.7
		416. B.	1.244	.505	2.46	.005	.005	.000	.012	.008	.004	.031	.012	.019	.048	.009	.039	.116	.017	.099	—	—	—	—	—	—	—	—	—	33700	168251	53.0
		9. B. 2	1.497	.604	2.48	.004	.003	.001	.008	.006	.002	.023	.008	.015	.034	.009	.025	.046	.010	.036	.096	.020	.076	.183	.015	.168	42100	146933	58.8			
	3d.	10. B. 2	1.513	.603	2.51	.004	.004	.000	.005	.005	.000	.014	.006	.008	.037	.014	.023	.060	.010	.050	.099	.016	.083	.141	.021	.120	45800	160377	62.5			
		11. B. 2	1.537	.597	2.57	.003	.001	.002	.014	.010	.004	.018	.009	.009	.027	.010	.017	.037	.010	.027	.074	.017	.057	.127	.016	.111	44200	157900	Crumbled at angles			
		12. B. 2	1.497	.604	2.48	.002	.002	.000	.004	.004	.000	.011	.008	.003	.020	.006	.014	.036	.012	.024	.061	.014	.047	.102	.019	.083	41300	144141	Bent and crumbled			
		13. B. 2	1.502	.603	2.49	.004	.004	.000	.009	.006	.003	.012	.007	.005	.026	.010	.016	.049	.010	.039	.083	.023	.060	.113	.018	.095	46700	163528	57.5			
		Mean	1.509	.602	2.51	.003	.002	.001	.008	.006	.002	.016	.008	.008	.029	.010	.019	.046	.010	.036	.083	.018	.065	.133	.018	.115	44025	154576	59.6			
Mixed { 3 parts No. 1 3 parts No. 2 2 parts No. 3	3d.	417. B.	1.246	.500	2.49	.010	.010	.000	.015	.009	.006	.028	.012	.016	.042	.012	.030	.098	.014	.084	—	—	—	—	—	—	—	—	30800	156863	57.5	
		420. B.	1.250	.507	2.47	.008	.008	.000	.010	.006	.004	.015	.009	.006	.039	.017	.022	.081	.018	.063	—	—	—	—	—	—	—	—	34600	171384	57.0	
		427. B.	1.246	.505	2.47	.005	.005	.000	.010	.008	.002	.022	.012	.010	.035	.012	.023	.065	.013	.052	—	—	—	—	—	—	—	—	33200	165755	52.6	
		428. B.	1.260	.503	2.50	.001	.001	.000	.006	.004	.002	.023	.005	.018	.047	.014	.033	.070	.015	.055	—	—	—	—	—	—	—	—	—	34600	174120	58.8
		Mean	1.250	.504	2.48	.006	.006	.000	.010	.007	.003	.022	.010	.012	.041	.014	.027	.078	.015	.063	—	—	—	—	—	—	—	—	33300	167030	56.5	

Summary of the preceding Mean Results of the Compressive Strength of Cast Iron.

Kind of Cast Iron.	Of what fusion.	DIMENSIONS OF SAMPLES.			DEPRESSION OR PERMANENT SET UNDER THE DIFFERENT PRESSURES OF									Break- ing weight.	Strength per square inch. $S = \frac{w}{\text{area}}$	Angle of fracture.
		Length.	Diamete- r.	Ratio $\frac{l}{d}$.	10000	15000	20000	25000	30000	35000	40000	45000	50000			
					lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.			
No. 1 Iron	2d.	1.513	.603	2.51	.000	.005	.024	.067	.172	—	—	—	—	28550	99770	52°.0
	3d.	1.508	.603	2.50	.000	.002	.004	.016	.048	.103	.124	—	—	39850	139540	57°.7
Nos. 1 and 3 mixed	2d. and 3d.	1.248	.503	2.48	.000	.004	.015	.036	.089	—	—	—	—	33500	168589	53°.7
Nos. 1 and 2 mixed	2d.	1.506	.603	2.49	.001	.002	.011	.031	.067	.161	—	—	—	39150	136868	52°.7
	3d.	1.244	.505	2.46	.000	.004	.019	.039	.099	—	—	—	—	33700	168251	53°.0
Nos. 1, 2, and 3 mixed	2d.	1.509	.602	2.51	.001	.002	.008	.019	.036	—	—	—	—	44025	154576	59°.6
	3d.	1.250	.504	2.48	.000	.003	.012	.027	.063	—	—	—	—	33300	167030	56°.5

Compressive Strength of Cast Steel. West Point Foundry, 1851.

Kind of Cast Steel tested.	Mark of sam- ples.	DIMENSIONS OF SAMPLES.			DEPRESSION OR PERMANENT SET UNDER THE DIFFERENT PRESSURES OF								Break- ing weight.	Strength per square inch equal to $S = \frac{w}{\text{area}}$.	
		Length.	Diam- eter.	Ratio $\frac{l}{d}$.											
					10000 lbs.	15000 lbs.	20000 lbs.	25000 lbs.	30000 lbs.	35000 lbs.	40000 lbs.	45000 lbs.			50000 lbs.
Not hardened	1	1.021	.400	2.55	.006	.019	.064	.209	—	—	—	—	—	25000	198944
Hardened; low temper; chipping chisels	2	.995	.402	2.47	.000	.000	.000	.000	.003	.008	.023	.070	—	45000	354544
Hardened; mean temper; turning tools	3	1.016	.403	2.52	.000	.000	.000	.000	.002	.006	.016	.028	.070	50000	391985
Hardened; high temper; tools for } turning hard steel	4	1.005	.405	2.48	.000	.000	.000	.000	.000	.004	.010	.066	—	48000	372598

NOTE.—All the samples of steel tested were cut from the same bar. No. 1 remained unchanged, as made at the steel manufactory. Nos. 2, 3, and 4, were all hardened, and the temper afterwards drawn down in different proportions.

The samples submitted to the test of compression, were all small cylinders, the lengths of which were generally two and a half times their diameters. Bars of greater length than three diameters, are liable to bend under the pressure before the fracture occurs. And if the length be less than two diameters, the fracture in its regular form may not be fully developed, and a portion of the sample may be pulverized, or reduced to small grains.

The ends of each sample were made perfectly parallel, and perpendicular to the axis; so that all parts of the sample would be equally pressed.

The difference, in capacity to resist compression, between the lowest and the highest grades of cast iron, is about as one to two. And the best samples of cast iron, approach nearly to common unhardened cast steel. The hardening and tempering of cast steel has a very great influence upon its quality. Its capacity to resist compression is thereby nearly doubled.

HARDNESS OF METALS.

The comparative softness, or hardness of metals, is determined by the bulk of the cavities, or indentations, made by equal pressures; the softness being as the bulk directly, and the hardness, as the bulk inversely. The instrument used, for making the indentations, is represented in plate XVI, figures 1, 2, 3, and 4.

The form of the indenting part of it, is a pyramid; the sides, and opposite angles of its base, are equal. The longest diagonal of its base is 1 inch; the shortest .2; and the height of the pyramid is .1. The planes of the sides intersect, at the penetrating edge, at an angle of 90°. The unit of measure adopted in representing the indentations, is one-tenth of an inch.

The area of the base, of the indenting tool = $\frac{10 \times 2}{2} = 10$ square tenths, and its height being 1, the cubic content of the pyramid is 3.333 tenths. A pressure of 10,000 pounds, on the base of the pyramid, makes an indentation, in the softest metals used in guns, about 9 tenths long. The maximum indentation of the instrument, $3\frac{1}{3}$ cubic tenths, is therefore assumed as the type of extreme softness; and, as the 0 of hardness.

The extremes of variation, in the metals tried, under a pressure of 10,000 pounds, were as follows:

Kind of Metals.	Mark of samples.	INDENTATIONS.		Hardness.
		Length.	Bulk.	
Soft Bronze	2. H. S. }	9.000	2.430	4.57
No. 1 pig Iron	3. P. C. }			
Hard cast Iron	385. B.	4.633	.332	33.51

Example of the method of computation—

Sample 1. *P.* 23, length of indentation = 7.5.

Then, as length $10.^3$: bulk 3.333 :: $(7.5)^3$: 1.406 = bulk,

and inversely, $(7.5.)^3$: 3.333 :: $10.^3$: 7.901 = hardness.

Or, by logarithms:

For bulk 3.333 log. 0.5228787

Divided by . . . $10.^3 = 1000$ log. 3.0000000

Constant log. for bulk $\bar{3}.5228787$

Length of indentation $(7.5)^3$ log. 2.6251839

Bulk = 1.406 0.1480626

For hardness . . . $10.^3$ log. 3.0000000

Multiplied by . . . 3.333 0.5228787

Constant log. for hardness 3.5228787

Divided by length $(7.5)^3$ log. 2.6251839

Hardness = 7.901 0.8976948

In the following tables, the density of the several samples tested, is added, to show the relation of hardness and density.

HARDNESS OF METALS.

Indentation under a Pressure of 10,000 Pounds.

KIND OF METAL.		Mark of samples.	Density.	INDENTATION; MEASURED IN TENTHS OF AN INCH.		Hardness.
Greenwood Iron.	Of what fusion.			Length.	Bulk.	
No. 1. { Rough pigs Moulded bars	{ 1st. {	1. P. 23	6.974	7.500	1.406	7.90
		1. P. 24	7.035	7.400	1.351	8.23
		17. B. 1	7.085	6.950	1.119	9.30
		Mean	7.032	7.283	1.292	8.48
No. 2. Rough pigs	{ 1st. {	2. P. 25	7.220	5.700	.616	18.00
		2. P. 26	7.086	7.000	1.143	9.72
		Mean	7.153	6.350	.879	13.86
No. 3. { Rough pigs Moulded bars	{ 1st. {	3. P. 27	7.244	5.500	.555	20.03
		3. P. 28	7.247	5.500	.555	20.03
		18. B. 1	7.235	5.666	.606	18.32
		19. B. 1	7.193	4.966	.408	27.21
		Mean	7.230	5.408	.531	21.40
No. 1 Iron. Moulded Proof bars	{ 2d. {	1. B. 2	7.091	6.333	.847	13.12
		2. B. 2	7.051	7.000	1.143	9.72
		3. B. 2	7.085	6.333	.847	13.12
		4. B. 2	7.082	6.666	.988	11.25
		5. B. 2	7.116	6.250	.814	13.65
		15. B. 2	7.090	6.500	.915	12.14
		Mean	7.086	6.514	.925	12.16
		16. B. 3	7.229	5.413	.529	21.01
	{ 3d. {	402. B.	7.167	5.666	.606	18.32
		Mean	7.198	5.539	.567	19.66
		4th. 434. B.	7.301	4.833	.376	29.52
10 parts No. 1, and 4 parts No. 3 8 parts No. 1, and 6 of No. 3 (Proof bars.)	{ 2d. and 3d. {	412. B.	7.259	4.883	.383	28.62
		413. B.	7.270	4.833	.376	29.52
		Mean	7.264	4.858	.379	29.07
Equal parts of Nos. 1 and 2 mixed (Proof bars.)	{ 2d. {	6. B. 2	7.189	5.583	.580	19.15
		8. B. 2	7.150	5.833	.662	13.69
		Mean	7.170	5.708	.621	16.41
	{ 3d.	416. B.	7.272	5.000	.417	26.67

HARDNESS OF METALS.

Indentation under a Pressure of 10,000 Pounds—Continued.

KIND OF METAL.		Mark of samples.	Density.	INDENTATION; MEASURED IN TENTHS OF AN INCH.		Hardness.	
Greenwood Iron.	Of what fusion.			Length.	Bulk.		
3 parts of No. 1 } 3 parts of No. 2 } Mixed 2 parts of No. 3 } (Proof bars.)	2d.	9. B. 2	7.224	5.416	.530	20.97	
		10. B. 2	7.250	5.000	.417	26.67	
		11. B. 2	7.272	5.033	.425	26.14	
		12. B. 2	7.265	5.500	.555	20.03	
		13. B. 2	7.246	5.083	.438	25.38	
	Mean	7.249	5.166	.460	24.17		
		Mean	7.251	5.200	.471	23.89	
		3d.	420. B.	7.346	4.666	.339	32.80
			427. B.	7.356	4.850	.380	29.22
			428. B.	7.318	4.833	.376	29.52
Mean	7.340		4.783	.365	30.51		
3d.	402. H.	7.093	6.333	.847	13.12		
	402. H. O.	7.088	6.433	.887	12.52		
	Mean	7.090	6.383	.867	12.82		
	No. 1 Iron. (Gun-heads.)	4th.	433. H.	7.257	5.466	.544	20.40
433. H. O.			7.257	5.166	.460	24.17	
434. H.			7.258	5.416	.530	20.97	
434. H. O.			7.256	5.333	.506	21.97	
Mean		7.257	5.345	.510	21.88		
10 parts No. 1, and 4 parts No. 3 } 8 parts No. 1, and 6 parts No. 3 } (Gun-heads.)	2d. and 3d.	412. H.	7.179	5.583	.580	19.15	
		412. H. O.	7.159	5.916	.690	16.09	
		413. H.	7.224	5.666	.606	18.32	
		413. H. O.	7.218	5.450	.540	20.59	
	Mean	7.195	5.654	.604	18.54		
Equal parts of Nos. 1 and 2 (Gun-heads.)	3d.	416. H.	7.228	5.600	.585	18.98	
		416. H. O.	7.228	5.500	.555	20.03	
	Mean	7.228	5.550	.570	19.50		
3 parts No. 1 } 3 parts No. 2 } Mixed 2 parts No. 3 } (Gun-heads.)	3d.	417. H.	7.244	5.166	.460	24.17	
		417. H. O.	7.249	4.916	.396	28.05	
		420. H.	7.267	5.050	.429	25.90	
		420. H. O.	7.270	5.283	.491	22.60	
		427. H. O.	7.265	5.250	.482	23.04	
		428. H.	7.262	5.500	.555	20.03	
		428. H. O.	7.267	5.050	.429	25.90	
	Mean	7.261	5.173	.463	24.24		

HARDNESS OF METALS.

Indentation under a Pressure of 10,000 Pounds—Continued.

KIND OF METAL.		Mark of samples.	Density.	INDENTATION; MEASURED IN TENTHS OF AN INCH.		Hardness.
Amenia Iron.	Of what fusion.			Length.	Bulk.	
2 parts 1, 2, and 3, of 2d. fusion } 1 part 1, 2, and 3, of 3d. fusion }	2d. and 3d. {	384. H. { 384. H. O. {	7.270 7.271	5.333 5.333	.506 .506	21.97 21.97
All of No. 2	3d. {	385. H. { 385. H. O. {	7.268 7.264	5.000 5.333	.417 .506	26.67 21.97
4 parts 1, 2, and 3, of 2d. fusion } 1 part 1, 2, and 3, of 3d. fusion }	2d. and 3d. {	386. H. { 386. H. O. {	7.258 7.258	5.333 5.333	.506 .506	21.97 21.97
(Gun-heads.)		Mean	7.265	5.277	.491	22.75
Nos. 1, 2, and 3 mixed No. 2	2d. and 3d. 3d.	384. B. 385. B.	7.344 7.354	5.000 4.633	.417 .332	26.67 33.51
Nos. 1, 2, and 3 mixed	2d. and 3d.	386. B.	7.327	5.166	.460	24.17
		Mean	7.342	4.933	.403	28.12
Rough furnace pigs	1st. {	Ame. 5 { 3. P. C. {	6.974 6.944	8.000 9.000	1.707 2.430	6.51 4.57
		Mean	6.959	8.500	2.068	5.54
Large cylinders	2d.	833. C. 2	7.165	6.666	.988	11.25
(Gun-heads.) $\frac{3}{4}$ of 3d. fusion $\frac{1}{4}$ of 4th. fusion	3d. and 4th. {	834. H. { 834. H. O. { 845. H. { 845. H. O. {	7.348 7.353 7.321 7.302	5.100 5.500 5.533 5.366	.442 .555 .565 .515	25.13 20.03 19.67 21.57
		Mean	7.331	5.375	.519	21.60
(Gun-heads.) Kent, 2d. fusion, $\frac{3}{12}$ Amenia, 3d. fusion, $\frac{5}{12}$ Amenia, 4th. fusion, $\frac{4}{12}$	2d., 3d., and 4th. {	850. H. { 850. H. O. {	7.302 7.298	5.700 5.633	.617 .595	18.00 18.65
		Mean	7.300	5.666	.606	18.32
Tredegar Iron, from axis of 32 } pdr. gun No. 587 }	3d. {	587. 1 { 587. 2 { 587. 3 {	7.241 7.308 7.302	5.933 5.633 5.883	.696 .596 .679	15.96 18.65 16.37
		Mean	7.284	5.186 5.816	.657	16.99

HARDNESS OF METALS.

Indentation under a Pressure of 10,000 Pounds—Continued.

KIND OF METAL.		Mark of samples.	Density.	INDENTATION; MEASURED IN TENTHS OF AN-INCH.		Hardness.
Bronze.	Of what fusion.			Length.	Bulk.	
9 pdr. gun, made at Seville, in Spain, 1802	—	S. 1	8.656	8.883	2.337	4.75
		S. 2	8.653	8.250	1.972	5.94
		S. 3	8.676	8.833	2.298	4.84
		Mean	8.662	8.655	2.202	5.18
6 pdr. bronze guns, Boston, 1850	—	2. H. S.	—	9.000	2.430	4.57
		H. 2	—	8.900	2.350	4.73
		Mean	—	8.950	2.390	4.65
Wrought iron, made at Crown Point, New York	—	No. 5	7.772	6.500	.915	12.14
		No. 6	7.832	6.833	1.063	10.45
		No. 7	7.858	6.750	1.025	10.84
		No. 8	7.704	6.783	1.040	10.68
		Mean	7.791	6.716	1.011	11.03

Recapitulation of Preceding Mean Results.

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Indentations, in different Forms, under a Pressure of 10,000 Pounds.

Kinds of Metals.		INDENTATIONS.		Mark of samples.
		Dimensions.	Bulk.	
Bronze.	Pyramid, as in the foregoing	Length, 8.900	2.350	H. 2
	Cones { Height, equal $\frac{1}{2}$ of base	Diameter, 2.500	2.045	
	{ Height, equal $\frac{1}{10}$ of base	Diameter, 3.933	1.592	
Cast iron.	Pyramid, as above	Length, 5.500	0.555	3. P. 28
	Cones { Height, equal $\frac{1}{2}$ of base	Diameter, 2.000	1.047	
	{ Height, equal $\frac{1}{10}$ of base	Diameter, 2.200	0.279	
	Pyramid, as above	Length, 5.600	0.585	416. H.
	Cone—height, equal $\frac{1}{2}$ of base	Diameter, 1.733	0.682	

Indentations, under different Pressures, on the same Samples.

SAMPLES TESTED.			BULK OF INDENTATIONS, UNDER PRESSURES OF—					
Marks.	Density.	Tenacity.	2500 pds.	5000 pds.	7500 pds.	10000 pds.	12500 pds.	15000 pds.
2. B. 2	7.051	18922	.131	.417	.738	1.143	1.582	2.233
17. B. 1	7.085	16424	.162	.369	.814	1.119	1.872	2.233
427. H.	7.256	—	.069	.274	.304	.667	.738	1.492
12. B. 2	7.265	39177	.052	.143	.304	.555	.667	.915
427. B.	7.356	32697	.056	.115	.247	.380	.601	.650
Mean Indentations			.092	.264	.481	.773	1.092	1.505
The weights are as			1	2	3	4	5	6
Indentations are as			1.000	2.869	5.228	8.402	11.870	16.359
The square roots of the cubes } of the weights are			1.000	2.828	5.196	8.000	11.180	14.696

It appears from the results, given in the preceding tables, that the hardness of iron, generally coincides with its density. And also, that the cavities made by different pressures, in the same metal, are nearly as $p^{\frac{3}{2}}$; p , being the pressure.

Of the different forms of cavity made by the indenting tools, that of the pyramid is preferred. The cone, with an angle of 90° at its point, will make a cavity about equal in bulk to that made by the pyramid, under equal pressures; but the latter may be more accurately determined, because it makes a longer mark, and minute differences are thus rendered more sensible. The form of the pyramid may, however, be improved, by making the longest diagonal of its base 1.25 instead of 1., and by making its sides meet, in the penetrating edge, at an angle of 60° instead of 90° ;

the height remaining the same as the present. This would make a longer line, and mark minute differences more accurately.

A pressure less than 10,000 lbs. will probably be found better suited to the purpose.

A better standard of comparison, than that adopted in the preceding trial, may be found in some metal, of uniform density and hardness, easily obtained in all places. The silver coin of the country best fulfils these conditions. The bulk of the cavity, made in this by the adopted given pressure, may be assumed as the unit (1.) of hardness; and this, divided by the bulk of cavity in any sample tested, will denote the hardness of that sample, compared with silver coin.

In order to exhibit in one connected view, the results of all the different forms of testing, in different grades of iron; and to show the relation which any form of test bears to other forms; such of the samples as were tested in all forms, are collected in the following table, and arranged in the order of their respective densities, beginning with the lowest and ending with the highest.

Mark of samples.	Density.	Tenacity.	Transverse Strength.	Torsional Strength.	Compressive Strength.	Hardness.
2. B. 2.	7.051	18922	5776	5605	84529	9.72
15. B. 2.	7.090	20900	5940	5775	95692	12.14
1. B. 2.	7.091	20222	6185	6835	104357	13.12
5. B. 2.	7.116	23463	6437	6489	114504	13.65
8. B. 2.	7.150	24900	7234	7410	133321	13.69
402. B.	7.167	29985	6787	—	138666	18.32
6. B. 2.	7.189	30276	7646	8285	140415	19.15
9. B. 2.	7.224	37519	8682	9329	146933	20.97
16. B. 2.	7.229	30229	7857	8799	140415	21.01
13. B. 2.	7.246	39553	8603	—	163528	25.38
10. B. 2.	7.250	35835	8768	10025	160377	26.67
412. B.	7.259	36916	9996	10153	167752	28.62
12. B. 2.	7.265	39177	9732	10013	144141	20.03
413. B.	7.270	39373	9515	9351	169427	29.52
11. B. 2.	7.272	38585	8173	9477	157900	26.14
416. B.	7.272	40897	9212	10467	168251	26.67
428. B.	7.318	37920	8772	8362	174120	29.52
417. B.	7.340	27626	9014	9033	156863	—
420. B.	7.346	31589	9719	9610	171384	32.80
427. B.	7.356	32697	9590	9254	165755	29.22

By this it appears, that the resistance of iron to forces or strains of all kinds, increases, and that this increase advances quite regularly, with the

density, in all the lower and medium grades of density; but, with less regularity, in the highest grade.

The preceding tests are arranged, in the following table, in five separate divisions, each giving the mean of four tests; beginning with the first four, or lowest samples.

Division.	Density.	Tenacity.	Transverse.	Torsion.	Compression.	Hardness.	Proportion of Torsion and Compression.
1st.	7.087	20877	6084	6176	99770	12.16	1 to 4.78
2d.	7.182	30670	7587	8341	139834	18.03	1 to 4.56
3d.	7.246	35633	8806	9659	158018	25.42	1 to 4.15
4th.	7.270	39508	9158	9827	159930	25.59	1 to 4.05
5th.	7.340	32458	9274	9065	167030	30.51	1 to 5.00
Mean	7.225	31829	8182	8614	144916	22.34	1 to 4.51

This table shows, that the capacity of iron to resist breaking, or crushing forces, of any kind, increases with its density, in all cases excepting those in which the iron is of the highest grade of density; and in these, the same law prevails in three of the five qualities tested; viz: transverse, compression, and hardness. The most material of the deviations from the general law, is seen in the tensile strength. In this, there is a manifest diminution of strength, in the samples of highest density.

The quality of hardness, appears to correspond more nearly with density, than any other quality. Among the twenty samples compared, only two or three appear as exceptions to the law; and these may be regarded as anomalous, or, as having been caused by invisible cavities or defects in the interior of samples, which are not of unfrequent occurrence in iron of very high density. As iron of high density, when cast into bars of small bulk, is liable to become unsound and to contain small cavities, this cause may account, in some measure, for the diminished tensile strength in bars of high density.

The mean results, given in the bottom line of the above table, show the proportionate resistance, or values of S , which each form of testing bears to any other form. The values of S , in tension, and in compression, are as 1 to $4\frac{1}{2}$, in the mean of the whole; but vary from 1 to 4, to 1 to 5, in the different grades of iron. By this it appears, that the force required to break a bar of cast iron, when compressed in the direction of its length, is

about four and a half times greater, than is required to pull the same bar asunder.

In the foregoing tables, which give the results of the different methods of testing, the samples tested were all of Greenwood iron. The qualities of iron of other make, from other ores, may not exhibit the same relation to its density, as in the Greenwood, although the same general law, that other qualities increase or diminish with density, may prevail. No opportunity for making a general comparison, in this respect, of other makes of iron with Greenwood, occurred. But, a few samples of other iron were tested in the qualities of density, tenacity, and hardness, the results of which, compared with Greenwood, are given in the following table:—

Kinds of Iron.	Mark.	Density.	Tenacity.	Hardness.
Greenwood Iron. Gun-heads	416. H.	7.228	32446	18.98
	416. H. O.	7.228	32396	20.03
	417. H.	7.244	38542	24.17
	417. H. O.	7.249	36387	28.05
	385. H. O.	7.264	36088	21.97
	385. H.	7.268	37368	26.67
Amenia Iron. Gun-heads	850. H. O.	7.298	33679	18.65
	850. H.	7.302	31050	18.00
	845. H. O.	7.302	37333	21.57
	845. H.	7.321	36285	19.67
	834. H.	7.348	35545	25.13
	834. H. O.	7.353	37527	20.03
Tredegar Iron. Axis of 32 pdr. gun	587. 1	7.241	22712	15.96
	587. 3	7.302	24900	16.37
	587. 2	7.308	26746	18.65
Greenwood	Mean	7.247	35538	23.33
Amenia	Mean	7.321	35236	20.51
Tredegar	Mean	7.284	24786	16.99

A comparison of the mean results, of these three different kinds of iron, will show, that in tenacity, the Greenwood, and the Amenias, are very nearly equal; while in density, the Greenwood is much lower, and in hardness, much higher, than the Amenias. The Tredegar is, in density, a mean between the other two; but in both tenacity and hardness, it is much below either of them. It thus appears, that although the tenacity and hardness will generally be found to coincide with the density, in the different grades of iron of the same make, or from the same furnace, the density of any

one given make, will not indicate accurately, the hardness, or tenacity, of another, or different make.

A few trials were made to determine the strength of hollow cylinders, by the application of a central force. The force was applied by means of a conic frustrum, made of hardened cast steel; the taper of the frustrum, in proportion to its height, being as one to ten. To lessen the friction, a ring of cast steel—its interior being tapered to correspond with the frustrum, and its exterior made to correspond with the interior of the cylinder to be tested—is cut into four equal parts, in the direction of its axis, and is inserted within the cylinder, as a shield to protect the cylinder from abrasion, when the force is applied. The conic frustrum is inserted within this shield, and a measured force is applied to it, in the direction of its axis. The results of these tests are given in the following table:—

Bursting of Hollow Cylinders.

Mark of samples.	DIMENSIONS OF CYLINDERS.			Area of fracture.	Breaking force.	TENACITY PER SQUARE INCH, COMPUTED FROM		
	DIAMETERS.		Height.			Central force.	Tensile strain.	Ratio.
	Exterior.	Interior.						
Cast Iron.								
433. H.	8.422	6.40	1.008	2.0882	181000	88808	34137	2.60
434. H.	8.416	6.40	1.016	2.0482	180000	87882	33493	2.62
13. B.	1.816	.806	1.005	1.015	148000	145813	34936	4.17
All from same bar	1.560	.806	1.004	.757	130000	171730		4.91
	1.309	.805	1.004	.506	78000	154150		4.41
	1.050	.806	1.004	.253	38000	150200		4.30
12. B. 2	1.810	.810	1.000	1.000	148000	148000	39179	3.77
13. B. 2	1.812	.810	1.002	1.002	145000	144700	39553	3.66
14. B. 2	1.817	.812	1.015	1.015	150000	147776	36068	4.09
15. B. 2	1.812	.810	1.002	1.002	102000	101796	20900	4.87
18. B.	1.811	.801	1.016	1.016	160000	157475	34882	4.51
413. B.	1.815	.812	1.013	1.013	133000	131290	39373	3.33
427. H.	1.816	.810	1.006	1.006	157000	156064	38197	4.08
428. B.	1.810	.810	1.050	1.050	133000	126667	37920	3.34
428. H.	1.812	.803	1.008	1.008	157000	155754	37382	4.16
428. H. O.	1.812	.810	.999	.999	186000	186186	39553	4.73
434. B.	1.811	.807	1.001	1.001	143000	142857	35786	3.99
587. 2	1.812	.812	1.000	1.000	110000	110000	26746	4.11
Bronze.								
1. S.	1.615	.806	.516	.41744	70000	167689	41797	4.01
2. S.	1.616	.806	.506	.40986	62000	151271	33052	4.57
3. S.	1.616	.806	.800	.64800	95000	146605	36469	4.02

The first two samples, in the preceding tables, were large rings, cut from gun-heads in the part joining the muzzle, and were about one inch

square. The interior diameter of the rings was 6.4, equal to the bore of a 32 pdr. gun. The four samples next following, were all taken from the same bar, having the same diameter of $\frac{8}{10}$ inch; and were of the same height, but varied in thickness as 1, 2, 3, 4. The remaining samples, were all parts of the same bars which had been used in the determinations of density, and tensile strength by direct strain.

The direct cohesive power of the metals tested, is accurately represented in the column headed *Tensile strain*. By comparing the numbers in this column with those in the adjoining column, which represents the resistance to the central force, it will be seen that the latter exceeds the former, in the two large rings, as 2.6 to 1; and in all the small rings, as about 4 to 1. The ratio in the latter varies from 3.33 to 4.91, or as about 2 to 3.

The force applied in the direct tensile strain was all exerted in pulling the bars asunder; no part of it was expended in overcoming friction. The results thus obtained, must therefore be regarded as the true measure of the cohesive power, in the metals thus tried. In bursting the cylinders by an internal force, the conical plug slides over the shield within the cylinder, and one end of the latter slides over the bed on which it rests. The movement of these surfaces, which are exceedingly small compared with the pressure on them, must of necessity produce an excessive friction; and it appears that, in these small cylinders, about three-fourths of all the force exerted was expended in overcoming the friction, and that one-fourth of it, only, was effectively employed in rending the cylinder. The ratio of the force expended in friction appears to be variable, differing as 2 to 3.

In the large rings, the ratio of friction is not so great as in the small rings. This may be attributed to the circumstance that the conic frustrum employed in bursting them was much larger, and presented a greater surface to the shields through which it moved.

In determining the fitness of any metal for making cannon, its power to resist bursting by the action of an internal force, seems to be the most important quality to be ascertained. The methods adopted in these trials for determining this resistance, do not appear to be well adapted to the purpose. The disproportion between the actual cohesive power of the metal, as determined by direct tensile strain, and the apparent cohesion, resulting from the method of bursting, and the variable ratio of force

expended in friction by the latter, render the results unsatisfactory and unreliable.

The form of the instruments employed in bursting may be improved, by substituting the frustrum of a triangular pyramid of equal sides, for the conic frustrum, and by making the shield in three equal parts, instead of four; the inside of the shield to have three planes, conforming to the frustrum, and the exterior to be cylindrical, fitting the cylinders to be tested. The surfaces of the conic frustrum and its shield, cannot coincide in more than one position. In all its movements, the contact and the pressure will be on lines, and not on surfaces; and will tend to produce abrasion, and to augment friction. With the triangular frustrum, the pressure will be equally distributed over the whole surface of the planes of the shields, and over all the interior surface of the cylinder.

It was designed to try the method of bursting cylinders by applying the force in the form of blows on the conic frustrum, as this would resemble more nearly the manner in which the force acts in cannon when fired: but when it was found that the friction was so irregular, and absorbed so large a portion of the force employed, the design was abandoned.

The most accurate method of testing cylinders would be, to burst them by hydrostatic pressure: but the mechanical arrangements necessary to prevent the escape of water from the cylinders, and for the effective action of the valves and pistons in the force-pump, under the high pressure employed, are exceedingly difficult in construction and working.

In some experiments made in bursting cannon by this method in 1844, the greatest force which we succeeded in obtaining was 20,000 pounds per square inch. This force burst a cylinder of very strong iron, the thickness of which was equal to its interior radius; and, although several old guns, of the usual proportions, were burst with a much less pressure than 20,000 pounds, an instrument capable of exerting a greater force, would be necessary for testing in this form generally.

Mr. Barlow, in his investigation of the strength of hollow cylinders, assumes the hypothesis,—that the area of the circular ring formed by a cross section through the cylinder will remain the same, whatever extension the cylinder may undergo, and that each successive circular lamina, from the interior to the exterior surface of the cylinder, offers a less and less resistance to the interior strain. Upon this hypothesis, he demonstrates that the

law of resistance, of each successive lamina, is inversely as the square of its distance from the centre. As this law is of the highest importance in determining the proper thickness of metal in cannon, its accuracy should, if possible, be practically demonstrated. As a preliminary effort to gather facts which might prove useful in such an investigation, some of the cylinders tested, were measured while under strain, and the results are given in the following table:—

Extension of Hollow Cylinders, by the application of an Internal Force.

Force applied.	BRONZE—3. H.			BRONZE—3. S.			CAST IRON—13. B. 2.		
	DIAMETERS.		Area of cross section.	DIAMETERS.		Area of cross section.	DIAMETERS.		Area of cross section.
	Exterior.	Interior.		Exterior.	Interior.		Exterior.	Interior.	
0000	1.710	.8060	1.7864	1.616	.8060	1.5408	1.309	.8050	.83681
1000	1.710	.8060	1.7864	1.617	.8091	1.5394	1.3093	.8061	.83603
2000	1.711	.8080	1.7865	1.617	.8101	1.5381	1.310	.8083	.83468
3000	1.712	.8096	1.7872	1.619	.8140	1.5382	1.311	.8102	.83432
4000	1.714	.8128	1.7885	1.620	.8160	1.5382	1.312	.8114	.83486
5000	1.716	.8148	1.7913	1.622	.8208	1.5372	1.313	.8126	.83439
6000	1.719	.8215	1.7908	1.628	.8382	1.5298	1.314	.8141	.83554
7000	1.726	.8290	1.8000	1.647	.8662	1.5412	1.315	.8153	.83607
8000	1.736	.8485	1.8015	1.660	.8948	1.5354			
9000	1.743	.8629	1.8013	1.681	.9232	1.5499			
10000	1.758	.8832	1.8147						
11000	1.768	.8971	1.8230						
	CAST IRON—428. H.			CAST IRON—428. H. O.			CAST IRON—484. B.		
	DIAMETERS.		Area of cross section.	DIAMETERS.		Area of cross section.	DIAMETERS.		Area of cross section.
	Exterior.	Interior.		Exterior.	Interior.		Exterior.	Interior.	
0000	1.812	.8030	2.0723	1.8120	.8100	2.0635	1.811	.8070	2.0644
5000	1.812	.8030	2.0723	1.8120	.8100	2.0635	1.812	.8124	2.0604
8000	1.813	.8053	2.0722	1.8127	.8124	2.0624	1.814	.8166	2.0607
10000	1.814	.8067	2.0733	1.8130	.8137	2.0616	1.814	.8177	2.0593
12000	1.815	.8085	2.0739	1.8134	.8151	2.0609	1.815	.8205	2.0585
14000	1.816	.8110	2.0736	1.8140	.8171	2.0600	1.815	.8211	2.0578

The exterior diameters were measured by sliding calipers, which measure thousandths of an inch accurately. The interior diameters were measured by the movement of the conic frustrum, determined by a graduated tapered rule of wood, prepared in haste while engaged in testing the cylinders. The accuracy of these interior measures are therefore less reliable than those of the exterior.

The areas resulting from these measures, it will be seen, are somewhat irregular; but as their deviations are comparatively small, and are in some

instances greater and in others less than the original area, they may be attributed to inexact measures. The general range of the results appears to sustain Mr. Barlow's hypothesis. Similar trials with cylinders of larger dimensions, and with instruments suitable for measuring minute changes with accuracy, would probably confirm it.

A more satisfactory method for determining the law of resistance, in large hollow cylinders, to an internal force, would be to test them by hydrostatic pressure. In an experiment for this purpose, a number of cylinders, of equal dimensions, should be cast from the same iron, and be uniformly cooled. All of them should be bored out to the same interior diameter, and by turning down the exterior, be reduced to different thicknesses, varying in some equal definite portions of the interior diameter.

In the experiments referred to, made in 1844, by hydrostatic pressure, no difficulty was found in measuring accurately the internal force exerted. The friction of the piston, which communicated motion from the pressure within the gun to the weighing apparatus, was reduced to a minimum, and satisfactory means were found for an exact measurement of this friction.

Cylinders prepared as above suggested, and burst by hydrostatic pressure, would give reliable results, showing, practically, the actual resistance each had opposed to a known pressure.

In order that the various qualities of different metals may be readily compared, and that the variations which occur in each may be seen at one view, results collected from the preceding tables, and from all the forms in which the several metals were tested, are given in the following table:—

Various Qualities of Different Metals.

Metals.		Density.	Tenacity.	Trans-verse Strength.	TORSION.		Compressive Strength.	Hardness.
					At $\frac{1}{2}$ degree.	Ultimate.		
Cast iron.	{ Least	6.900	9000	5000	3861	5605	84529	4.57
	{ Greatest	7.400	45970	11500	7812	10467	174120	33.51
Wrought iron.	{ Least	7.704	38027	6500	3197	—	40000	10.45
	{ Greatest	7.858	74592	—	4289	7700	127720	12.14
Bronze.	{ Least	7.978	17698	—	2021	5511	—	4.57
	{ Greatest	8.953	56786	—	—	—	—	5.94
Cast steel.	{ Least	7.729	—	—	—	—	198944	—
	{ Greatest	7.862	128000	23000	—	—	391985	—

A prominent feature of this table, is that which shows the great difference between the lower, and the higher grades of the same metal. In cast iron, the density differs as 6.9 to 7.4, a difference equal to 31 pounds per cubic foot; in tenacity, or direct cohesion, it differs as 45,970 to 9,000 pounds per square inch, or as 5 to 1; and, in transverse, torsion, and compression, it differs as 2 to 1, and in hardness, as 7 to 1. The bronze varies in tenacity from 56,786 to 17,698, more than 3 to 1; and in density, it is as 8.953 to 7.978, equal to 61 pounds in the cubic foot.

The differences here mentioned are the more worthy of note, because, in most of the publications which treat of the strength of materials, the resistance which metals oppose to various strains is mentioned, as if there was no very material difference between the inferior and superior qualities. The mechanical properties of metals which are the most essential in the manufacture of cannon, are *tenacity* and *hardness*, and, as holding an intimate relation to these, *density* may be added. These properties, with the testing instruments as now perfected, are most readily and accurately ascertained. A half day's labor of a workman is sufficient for cutting out a sample from a gun head, and for preparing it for testing; and it may be tested in all these forms in an hour.

The resistance of metals to transverse, torsional, and compressive forces, although less important in cannon, is of the highest importance to the engineer in designing and constructing machinery, and in public works generally. The chief purpose of the preceding experiments was to improve the quality of cannon, by endeavoring to ascertain the different qualities of the metal used in making them, and the best methods of treating it, in the processes of melting, casting, and cooling it. Such investigations as were directly applicable to this purpose, claimed special attention and were diligently pursued; while those relating to transverse, torsional, and compressive resistance, were regarded as incidental, and were undertaken only when convenient opportunities offered. This will account for any incompleteness, or want of fulness, in the tables which relate to this latter class of tests. The deflections, and the permanent set under different pressures, and the pressure and deflection at which the permanent set first occurs, in this class of tests, are not so minutely reported as is desirable. The form of the bars tested, was suitable for ascertaining the ultimate resistance; but for the purpose of determining the deflection and set, with the exactness required

for developing the laws which prevail in such strains, the bars should have greater length in proportion to their breadth and diameter.

The success which has attended these efforts to improve the quality of cannon, may be best exhibited, by contrasting the strength of the cannon made prior to 1841, when the present system of Inspection and Proof was commenced, with those made in 1851.

By the report of the late Captain Walbach, who tested samples taken from all the cannon, at all the Forts and Arsenals, which were made prior to 1841, it appears that the whole number of guns thus tested was 2824. From the results obtained, they were divided into three classes; the first, being regarded as of good quality and serviceable; the second, as doubtful, or fit for limited service only; and the third, as unserviceable.

The mean density and tenacity of the cannon, of each class, are as follows:—

	Density.	Tenacity.
First class	7.200	26430
Second class	7.143	23467
Third class	7.100	21018
Mean of all guns on hand cast prior to 1841	7.148	23638

The mean density and tenacity of the guns last made, at the Boston, West Point, and Fort Pitt Foundries, in 1851, as stated in the preceding tables, are as below:—

	Density.	Tenacity.
Amenia Iron, in 27, 32 pdr. guns	7.316	35294
Greenwood Iron { 4, 32 pdr. guns	7.260	38093
{ 4, Columbiads, 8 and 10 inch	7.290	39934
Mean of guns cast in 1851	7.289	37774

The system of Inspection and Proof which prevailed prior to 1841, consisted, chiefly, in firing the guns with heavy charges of powder and balls. This method of proof gave no other testimony of the strength of the iron, than its capacity to resist a given strain. It divided all qualities of iron into two classes only, one that *could*, another that *could not*, resist the given strain. The results of such proofs gave no information by which iron, that would barely endure the strain, could be distinguished from that which was greatly superior; they could do no more than indicate what iron *to reject*, in future castings. If the given strain was successfully endured, both the

founder and the inspector were content; the prescribed standard was reached, and neither could have any motive for endeavoring to surpass it, because there were no tests known by which any excellence, above that, could be made manifest.

This system of Inspection and Proof was superseded, in 1841, by the present regulations, on the recommendation of the Ordnance Board. These regulations provide for the constant attendance of an officer at the foundries, while the cannon are making, who examines and tests the metal, before it is used; witnesses its melting and casting; and tests the metal in the first gun made, before the second one is cast. If the first one proves unsatisfactory, such changes are made, either in the material, or in its treatment, as will tend to produce the desired result. This practice, of ascertaining the quality of the materials used, and of the castings made, from day to day, as the work proceeds, enables the founder to distinguish the materials, to select those of best quality, and to treat them in the best manner. If these tests are satisfactory, the inspecting officer is assured of the good quality of the guns, before any proof by firing is made. And this supersedes the necessity of using excessive proof charges, in the final proof, which may do serious, and even fatal injury to guns, without bursting them, or leaving any visible marks of the injury. The benefits of this system, and of the practice under it, are more satisfactorily demonstrated by the fact, of its having increased the average strength of iron cannon from 23,638, to 37,774 pounds, per square inch.

This improvement in the quality of iron cannon has been greatly assisted by the proprietors of the foundries at which the experiments were made. Their practical knowledge of the qualities and treatment of iron; their suggestions and zealous coöperation in all experiments made, and the liberality with which they provided all needful facilities for the purpose; have contributed most materially to the success which has attended these efforts to improve the strength and safety of cannon.

The original material, upon which all the operations described in the preceding experiments were made, was pig iron in its crude state, the condition in which it comes from the smelting furnaces. The processes employed, in the production of iron from the ores, are not described. And it is in this branch of the iron manufacture, that we must seek for the causes of the widely different properties of pig iron, which are exhibited

in the preceding tables. These tables show, that some kinds of iron are susceptible of very great improvement, by different processes of treatment at the foundries; while other kinds are at their maximum strength in the crude pigs. The cause of this difference, in the susceptibility for change and improvement, remains to be ascertained. It will doubtless be found in the qualities of ores used, and in the processes of smelting them.

A chemical analysis, of a selected portion of the tested samples of iron, it is believed, would throw much light on this subject. As, for instance, in a kind of iron which is much changed and improved, by repeated fusions, we may suppose that some foreign substances contained in the crude pig, have been expelled, by this process; in such cases, it is important that the kinds and the quantities of foreign substances removed, and the proportions of either which may be found remaining, in the improved sample, should be known.

All the tested samples, referred to in the preceding statements, are deposited at the Washington Arsenal; and, as the chemical laboratory at the Pikesville Arsenal possesses all needful facilities for the purpose, I suggest that a portion of them be analyzed there, and that the following samples be selected for the purpose:—

<i>Amenia Iron.</i>				
	Fusion.	Mark.	Density.	Tenacity.
Crude pig iron . . .	1st.	Ame. 1,250	6.949	11,020
From large Cylinder . .	2d.	819, C.	7.069	15,942
From Gun-head . . .	3d.	819, H. O.	7.327	35,846

These were all of the same parcel of iron melted a second and a third time. The great change of quality, exhibited in these three samples, is remarkable; and is caused, so far as we know, solely by the process of remelting.

<i>Amenia Iron.</i>				
	Fusion.	Mark.	Density.	Tenacity.
Taken from large Cylinder . . .	2d.	833, C. 2	7.165	26126
Same iron, remelted Gun-head . . .	3d.	833, H. O.	7.316	35810
Small bars cast in gun mould, and cooled rapidly	Annealed	3d. 833, B. I.	7.274	27502
	Unannealed	3d. 833, B. O.	7.386	30163

All of the samples of this selection were of the same parcel of iron. The treatment of the first two, differs only, in the number of times melted.

The treatment of the last three samples, differs only in the times, and manner, in which each were cooled. They were all cast at the same melting; the liquid iron flowed from the same source, into each mould, at the same time; and the composition of each, at the instant when the flow ceased, must have been precisely the same in each and all of the samples. This experiment presents an interesting question, which can be solved by analysis only. Did the differences in the time and manner of cooling effect any change in the chemical constituents of the several masses: or, was the effect caused solely by a different aggregation, or arrangement of the particles?

Greenwood Iron.

	Fusion.	Mark.	Density.	Tenacity.
Rough crude pigs of the grades Nos. 1, 2, and 3	1st.	1. P. 23	6.974	14000
	1st.	2. P. 26	7.086	20404
	1st.	3. P. 27	7.244	34793

These samples were all from the crude pig iron, of the several grades of foundry iron, Nos. 1, 2, and 3, made at the same furnace, from the same ores; and they constitute the primitive stock of material, used in all the experiments which were made with the Greenwood iron.

	Fusion.	Mark.	Density.	Tenacity.
All of the same parcel of No. 1 iron, melted a se- cond, third, and fourth time	Pig 1st.	1. P. 23	6.974	14000
	Bars {	2d. 15. B. 2	7.090	20900
		3d. 16. B. 3	7.229	30229
		4th. 434. B.	7.301	35786
	Head 4th.	434. H.	7.257	33724

The first sample in this selection, is the same as the first in the preceding. The 2d. 3d. and 4th. samples, are the same iron, cast and cooled in like manner, and differ, only, in the number of times melted; and they exhibit the changes effected, in the mechanical properties of the same material, by repeated meltings only. The 5th. sample is from the same melting as the 4th., from which it differs only in cooling; being cast in a large mass and cooled slowly.

	Fusion.	Mark.	Density.	Tenacity.
Grades of Nos. 1, 2, and 3, mixed	Bar 3d.	427. B.	7.356	32697
	Head 3d.	427. H. O.	7.265	38197
	Gun 3d.	6. G. O. 86	7.304	45970

The first two of these are from the same melting of iron; the one, cast in a small bar and cooled rapidly, and the other cooled slowly in a gun head. This pair of samples affords a good example of the principle, mentioned in a former part of this report, that the process of repeated meltings may be extended so far, as to increase the density beyond the point best adapted to its greatest strength. This iron, when cast, was in its best condition for strength, in a large mass cooled slowly; but, in a small mass, its density was increased, and its tenacity diminished.

The last of the above samples is selected because of its being the strongest piece of cast iron ever tested; and for this reason, an analysis, which will give us its exact composition, is very desirable.

In making the above selections, such samples are chosen as will best exhibit the following particulars and characteristics, viz:—

1st. The properties which distinguish the different grades of iron, numbers 1, 2, and 3, made from the same ores, at the same Furnace.

2d. The changes in the mechanical properties of iron, produced by repeated meltings, of one of those grades, separately; showing the changes effected at each melting.

3d. The changes produced by repeated meltings, of the different grades of iron, mixed.

4th. The changes produced in iron of the same melting, and quality, by casting it into masses of different bulk, and by different methods of cooling.

The figures annexed to the several samples named, show that these changes are of a highly important character. In the Greenwood Iron, for instance, we see all varieties of strength, from 14,000 up to 45,900 pounds per square inch, which varieties are produced by different methods of melting and cooling the iron. Such an analysis as will show what changes occurred in the chemical constituents of the iron, in each sample, during these several processes, will be highly interesting and useful. Such foreign substances, as are commonly found in combination with cast iron, and the proportion in which the presence or absence of any one, contributes to its strength, or to its weakness, may then be determined.

MANUFACTURE OF BRONZE GUNS AT CHICOPEE,
MASSACHUSETTS, 1850.

Tests of Tin and Copper.

					Density.	Tenacity.
Banco Tin					7.297	2122
Lake Superior Copper.	{	Smelted at Copper Works, Pittsburg	{		8.757	25381
					8.694	23020
					8.702	22192
					8.694	24594
					8.667	24262
					8.657	23467
	{	Mean . .	{		8.695	23819
				Smelted at Revere Works, Boston .	8.632	22098
					8.559	27729
					8.683	25524
{	Mean . .	{		8.625	25117	
Mean of 9 samples					8.672	24252
Revere Copper.	{	Hammered		8.702	20700	
		Unhammered		8.523	20346	

Proportions of Tin and Copper used in making Bronze Guns.

	Density.	Tenacity.
Tin, 1 part	7.297	2122
Copper, 8 parts	8.672	24252
Mean proportional	8.519	21793
Mean of 83 guns	8.751	
Mean of 83 gun-heads	8.523	29655

Manufacture of Bronze Cannon by the Ames Company. Chicopee, Mass., 1850.

CASTINGS.			METAL USED.						TIME.			TEST OF SAMPLES.		FINISHED GUNS.		
Date.	Guns.	Foundry No.	Cliff mine Copper.	BRONZE.		Tin.	Parts of tin in 100 of all.	Total pounds.	In melting.	IN FUSION.		Density.	Tenacity.	Register number.	Density.	Weight.
				Heads.	Chips.					Copper.	Alloy.					
1850	6 pdr.	1	—	—	—	—	—	—	H. M.	Min.	Min.	8.448	27972	366	8.749	885
	"	2	—	—	—	—	—	—	—	—	—	8.439	29797	367	8.743	886
	"	3	—	—	—	—	—	—	—	—	—	8.475	23873	368	8.741	886
	"	4	—	—	—	—	—	—	—	—	—	8.468	26080	369	8.748	886
	"	5	—	—	—	—	—	—	—	—	—	8.517	27633	370	8.764	890
	"	6	—	—	—	—	—	—	—	—	—	8.520	28736	371	8.763	887
	"	7	—	—	—	—	—	—	—	—	—	8.499	28518	372	8.755	887
	"	31	—	—	—	—	—	—	—	—	—	8.453	33344	373	8.731	883
	"	33	—	—	—	—	—	—	—	—	—	8.466	31672	374	8.742	885
	"	33	—	—	—	—	—	—	—	—	—	8.420	32849	375	8.738	887
February 2 "																

April	5	.	.	6 pdr.	26	1048	1496	625	{ 131 8 }	11.111	3308	3.	3	18	22	8.477	28194	399	8.677	879
May	24	.	.	"	48	2104	—	—	262	11.073	4209	3.	27	13	11	8.603	27273	400	8.749	888
"	29	.	.	"	49	—	1369	465	9	.488	4210	2.	45	12	20	8.591	26306	401	8.752	885
"	29	.	.	"	50	1935	—	—	241	11.075	4210	2.	45	12	13	8.438	27361	402	8.746	887
"	29	.	.	"	51	—	1552	472	10	.491	4210	3.	18	12	23	8.631	29551	403	8.741	885
June	3	.	.	"	52	1896	—	—	236	11.069	4210	3.	18	12	17	8.424	29424	404	8.732	887
"	12	.	.	"	53	—	1588	480	10	.481	4211	3.	15	12	26	8.420	29285	405	8.732	885
"	12	.	.	"	55	1830	—	—	228	11.078	4211	3.	15	12	11	8.440	26482	406	8.752	885
"	21	.	.	"	56	—	1689	453	11	.511	4162	3.	50	8	20	8.446	27806	407	8.758	888
August	5	.	.	"	58	1513	—	—	189	11.104	4162	3.	50	8	10	8.476	25380	408	8.763	886
"	15	.	.	"	59	—	1873	575	12	.488	4161	3.	50	11	18	8.347	25562	409	8.746	885
"	24	.	.	"	60	1847	—	—	230	11.073	4161	3.	50	11	45	—	—	410	8.735	884
"	24	.	.	"	61	—	1753	320	11	.528	4165	3.	18	12	55	—	—	411	8.723	885
"	24	.	.	"	63	1761	—	—	220	11.110	4165	3.	18	12	10	8.494	26526	412	8.751	886
"	24	.	.	"	64	—	1798	375	11	.500	4162	3.	45	10	19	8.512	27889	413	8.747	884
"	24	.	.	"	66	1589	—	—	198	11.08	4162	3.	45	10	9	8.488	28648	414	8.767	890
"	24	.	.	"	67	—	1820	543	12	.51	—	—	—	—	18	8.469	28865	415	8.754	888
Mean of 46, 6 pdr. guns	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8.470	28658	—	8.740	885
March	19	.	.	12 pdr.	20	2089	—	—	261	11.106	4513	3.	33	10	14	8.536	24418	7	8.767	1769
"	28	.	.	"	25	1394	1598	552	13	.647	4213	3.	20	15	30	8.579	28065	8	8.758	1765
April	10	.	.	"	27	1630	2077	555	13	.491	4113	3.	42	20	28	8.490	27449	9	8.752	1766
"	15	.	.	"	28	1579	1747	520	13	.570	4062	3.	38	15	22	8.523	27537	10	8.761	1767
"	19	.	.	"	29	1564	1706	568	12	.525	4012	3.	55	11	15	8.466	26086	11	8.753	1766
"	26	.	.	"	30	1689	1664	577	12	.533	4011	3.	45	20	15	8.466	26086	11	8.753	1766
May	1	.	.	"	39	1783	1500	600	11	.521	4011	3.	45	20	15	8.501	27667	12	8.756	1769
"	6	.	.	"	44	1601	1468	527	8	.391	4008	3.	50	10	13	8.464	25514	13	8.751	1768
"	10	.	.	"	45	1876	1536	663	11	.491	4011	3.	35	13	17	8.579	32904	14	8.768	1773
"	10	.	.	"	45	—	1557	332	10	.526	4010	3.	10	25	18	8.490	26835	15	8.763	1771

Manufacture of Bronze Cannon by the Ames Company. Chicopee, Mass., 1850-1851--Continued.

CASTINGS.			METAL USED.					TIME.			TEST OF SAMPLES.		FINISHED GUNS.			
Date.	Guns.	Foundry No.	Cliff mine Copper.	BRONZE.		Tin.	Parts of tin in 100 of all.	Total pounds.	In melting.	IN FUSION.		Density.	Tenacity.	Register number.	Density.	Weight.
				Heads.	Chips.				H. M.	Min.	Min.					
1850			1912	—	—	239	11.111	4011	3. 43	12	13	8.308	23529	16	8.756	1769
May 15	12 pdr.	46	—	1473	377	10	.337	4010	3. 25	12	13	8.473	29739	17	8.765	1769
" 20	"	47	1862	1379	527	10	.522	4212	3. 25	13	12	8.457	25583	18	8.755	1771
June 7	"	54	1641	—	—	205	11.105	4209	3. 50	10	12	8.392	27579	19	8.688	1766
October 19	"	82	—	1880	474	12	.507	4219	3. 55	13	12	8.537	34222	20	8.744	1766
" 25	"	83	392	2939	820	19	.500									
			576	—	—	71	10.970									
			—	2800	753	19	.453									
1851			Reverse copper.													
January 6	"	85	1075	—	—	134	11.08	4518	—	—	—	8.531	26183	21	8.646	1743
" 18	"	89	—	1971	1322	16	.37	6898	—	—	—	8.563	33821	22	8.689	1755
" 25	"	90	1451	—	—	181	11.090	6622	7. 00	H. M. 2. 30	15	8.526	31815	23	8.682	1757
" 31	"	92	2009	4282	965	19	.36	6853	5. 45	2. 30	30	8.711	33926	24	8.748	1776
			—	3174	1177	11	.25									
			3028	—	—	378	11.098									
			—	2690	747	10	.290									
Mean of 18, 12 pdr. guns	—	—	—	—	—	—	—	—	—	—	—	8.57	28493	—	8.739	1766

Note.—The metal for the last four guns was melted in a furnace of the Prussian model.

Manufacture of Bronze Howitzers by the Ames Company. Chicopee, 1850—1851.

CASTINGS.			METAL USED.						TIME.			TEST OF SAMPLES.		FINISHED HOWITZERS.		
Date.	Howitzers.	Foundry No.	Cliff mine Copper.	BRONZE.		Tin.	Parts of tin in 100 of all.	Total pounds.	In melt- ing.	IN FUSION.		Density.	Tena- city.	Register num ber.	Density.	Weight.
				Heads.	Chips.				H. M.	Copper.	Alloy.					
1850	12 pdr. howitzer	8	—	—	—	—	—	—	—	Min.	Min.	8.470	28076	95	8.754	787
September 4	"	9	—	—	—	—	—	—	—	—	—	8.488	28034	96	8.742	788
	"	69	1466	—	—	183	11.10	4073	3. 48	10	8	8.544	31477	97	8.778	791
	"	70	—	1772	659	13	.53	—	—	—	—	8.509	33985	98	8.753	791
	"	72	1275	—	—	159	11.09	4365	3. 20	12	8	8.604	24804	99	8.778	794
" 13	"	73	—	2236	680	15	.51	—	—	—	—	8.420	30227	100	8.778	790
" 28	"	76	918	—	—	114	11.05	4216	4. 10	8	9	8.571	28200	101	8.749	791
	"	77	—	1990	1178	16	.50	—	—	—	—	8.577	33157	102	8.749	793
October 3	"	78	728	—	—	91	11.11	4268	4. 16	10	8	8.572	27931	103	8.764	791
	"	79	—	2469	962	18	.55	—	—	—	—	8.570	29473	104	8.765	790
1851																
March 27	"	97	546	2031	800	80	—	3457	—	—	—	8.461	30804	105	8.688	783
Mean of 11, 12 pdr. howitzers	—	—	—	—	—	—	—	—	—	—	—	8.526	29652	—	8.754	790
June 12	32 pdr. howitzer	57	2112	—	689	264	11.111	5315	3. 47	10	12	8.499	29512	1	8.787	1931
August 10	"	62	2369	2235	—	15	.511	4911	3. 41	9	10	8.545	31461	2	8.786	1931
	"	65	—	1885	350	11	.49	4911	3. 57	10	12	8.634	33467	3	8.788	1931
September 9	"	71	2478	—	768	309	11.09	5065	4. 15	11	14	8.469	35309	4	8.765	1927
	"	74	2022	1914	—	252	11.08	4975	4. 01	10	14	8.697	35484	5	8.808	1927
" 19	"	75	980	—	862	15	.57	4996	3. 51	10	11	8.603	30741	6	8.778	1929
" 24	"	75	1524	2689	1164	20	.52	4917	3. 59	17	26	8.528	28546	7	8.736	1916
	"	80	—	2372	864	16	.49	4917	4. 07	11	12	8.756	30013	8	8.738	1924
October 8	"	81	1480	—	—	185	11.11	4917	—	—	—	8.591	31816	—	8.773	1927
" 9	"	80	—	2365	870	17	.52	4917	—	—	—	8.591	31816	—	8.773	1927
	"	81	1453	—	780	17	.52	4917	—	—	—	8.591	31816	—	8.773	1927
Mean of 8, 32 pdr. howitzers	—	—	—	—	—	—	—	—	—	—	—	8.591	31816	—	8.773	1927

The samples tested, and recorded in the preceding columns, were all taken from the gun-heads, at the end nearest the muzzle; and all, excepting eight of them, were cut out in the usual manner, with the axis of the sample parallel to the axis of the gun. The surface of their fracture, when tested, was therefore parallel to the face of the muzzle. The eight samples, numbered 31 to 38 inclusive, were taken out of rings which were cut from the front of the muzzles, the axis of the sample being in a plane perpendicular to the axis of the gun. The surface of fracture in these eight samples is in a plane which passes through the axis of the bore. The tenacity of these samples is much greater, than of those wherein the surface of fracture is parallel with the face of the muzzle, as will be seen by the following mean results:—

	Density of Guns.	Density of Heads.	Tenacity.
Mean of 36, 6 pdr. guns	8.7395	8.474	27762
Mean of 8, “ “	8.741	8.452	32692
Mean of the whole 44,	8.740	8.470	28658

This difference in the strength of samples, taken from the same part of the castings, made of the same materials, and treated in like manner, is too marked, and constant, to be attributed to any accidental differences attending the melting, casting, or cooling, of the metal. The density of the two classes of samples, and of the guns from which they were taken, do not differ essentially, but is lowest in the eight samples which have the highest tenacity. It appears, therefore, that the difference in the strength of the metal must be attributed to the different direction in which the tensile strain is applied; the resistance being greater, when the strain is parallel with a tangent, than when it is parallel with the axis of the gun. Why this should be so, or whether it is so in fact, in all ordinary cases, the trials yet made are not sufficient in number or variety to enable us to determine. The differences, and the apparent cause of them, are, however, sufficiently remarkable to merit further investigation.

It will be seen by the preceding statements, that the density of the gun-head samples is, uniformly, much less than the density of the entire gun when finished. The mean densities of all are as follows:—

	Gun-head samples.	Entire guns.	Difference.
46, 6 pdr. guns	8.470	8.740	.270
18, 12 pdr. guns	8.507	8.739	.232
11, 12 pdr. howitzers	8.526	8.754	.228
8, 32 pdr. howitzers	8.591	8.773	.182
—	—	—	—
83 castings, mean	8.523	8.751	.228

From this difference in density, it was inferred that the density of the metal, in the same casting, increases as the distance from the upper surface of the casting increases, and that probably the tenacity increases in like manner. A sufficient cause for such difference may appear in the fact, that the lower parts of the casting are under a heavier pressure, while the liquid metal is in the act of passing from the liquid to the solid state.

In order to ascertain whether these conjectures were correct, several guns were cast with additions to the breech, from which samples for testing could be taken without injury to the gun; and, in other castings, small bars were cast in the same mould with the gun, but separate from it. The annexed sketch, Plate X, Fig. 1, shows the additions cast on the breech, and the positions of the several samples. In the samples marked T, the surface of fracture is in a plane which passes *through* the axis of the bore; in those marked P, the fracture is in a plane perpendicular to the axis. The results are given in the following table:—

Foundry number of gun.	DENSITY.				TENACITY.		
	Breech. B. G. P.	Breech. B. G. T.	Head. H.	Gun.	Breech. B. G. P.	Breech. B. G. T.	H. Gun-head.
71	8.830	8.831	8.469	8.765	36772	45965	35309
	8.840	—	—	—	45569	—	—
72	8.841	8.813	8.604	8.778	51095	46216	24804
73	8.828	8.812	8.420	8.778	48753	53702	30227
89	8.804	—	8.563	8.689	51574	—	32821
Mean	8.828	8.819	8.514	8.752	46752	48628	31040

These results show, that the breech samples greatly surpass the gun-heads, in both density and tenacity, and that in density, they exceed the entire gun, in a less degree.

Tests of Small Bars, compared with Gun-Heads.

Foundry number of guns.	DENSITY.				TENACITY.		
	SMALL BARS.		Gun-heads.	Finished guns.	SMALL BARS.		Gun-heads.
	A.	B.			A.	B.	
6	8.468	8.823	8.520	8.763	38427	47555	28736
7	8.629	8.569	8.499	8.755	38617	45722	28518
44	8.416	8.739	8.579	8.768	40064	53754	32904
45	8.571	8.749	8.490	8.763	36288	42652	26835
46	8.558	8.712	8.308	8.756	41129	46017	23529
47	8.480	8.843	8.473	8.765	38235	23854	29739
54	8.516	8.722	8.457	8.755	40459	44029	25583
57	8.715	8.424	8.499	8.787	54544	30405	29512
60	8.503	8.624	—	8.735	40255	47381	—
61	8.549	8.513	—	8.723	40659	38816	—
62	8.652	8.727	8.545	8.786	42238	53068	31461
65	8.686	8.368	8.634	8.788	52347	27633	33464
68	8.654	8.572	8.487	—	54531	44630	30690
73	8.491	8.587	8.420	8.778	41735	39785	30227
74	8.452	8.269	8.697	8.808	37676	29776	35484
86	8.584	8.536	8.357	—	46855	45473	31349
Mean	8.557	8.611	8.497	8.766	42754	41284	29859

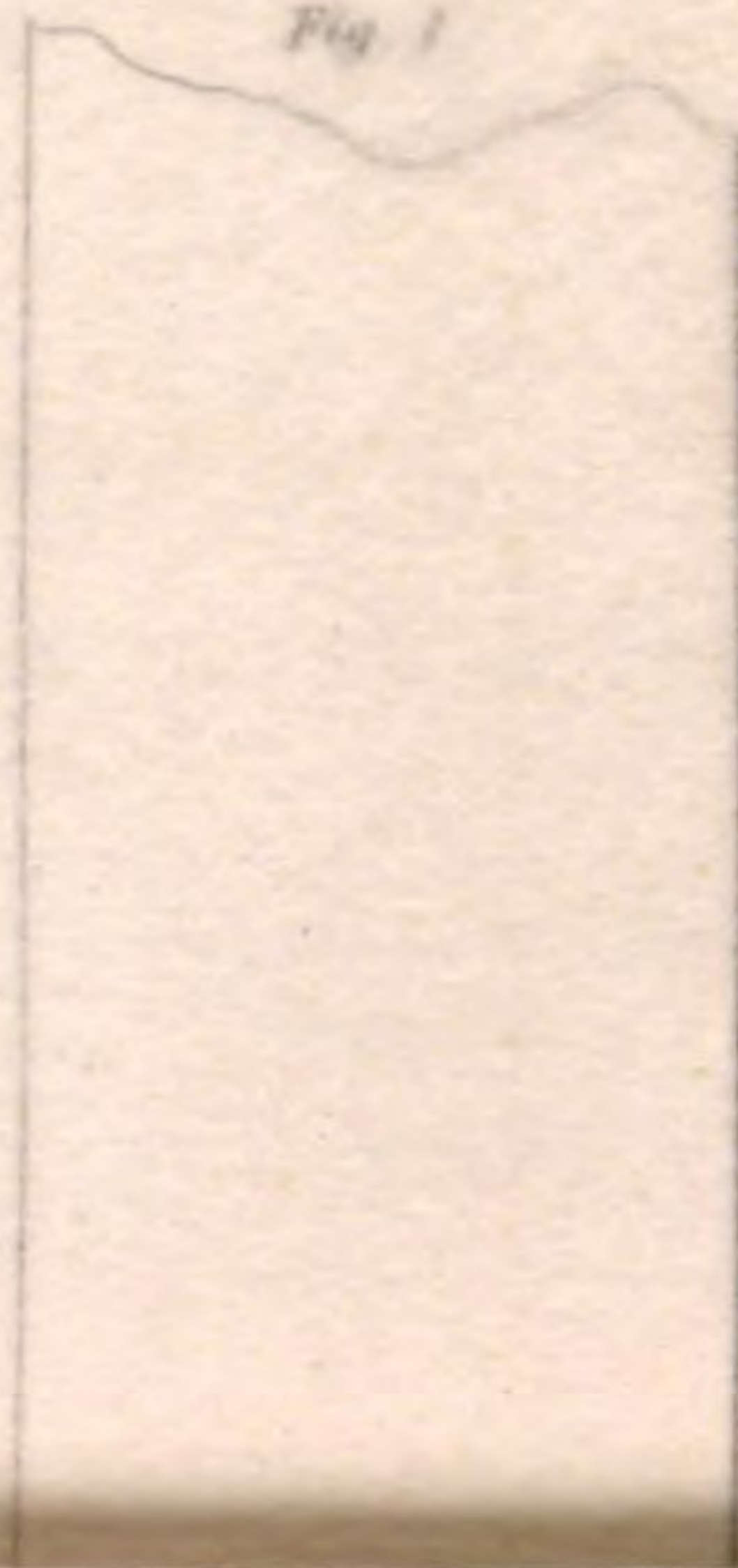
Summary of above Mean Results.

	Density.	Tenacity.
Gun-head samples	8.497	29859
Small bars { A, cast in upper part of mould	8.557	42754
{ B, cast in bottom of mould .	8.611	41284
Finished gun entire	8.766	—

The small bars were cast in the same mould with the guns. Those marked A were placed opposite the neck of the gun, and those marked B opposite the cascable. They were cast at the same time, and are composed of the same material as the guns, as the liquid metal flowed from the latter into the former while casting.

The same kind of copper, and of tin, mixed in the same proportions, and melted in like manner, was used in all the castings; yet the table exhibits a remarkable diversity in the results, in the samples of each class, as well as of each casting. The gun-heads are lowest in both density and tenacity. The density of the entire gun exceeds the density of the small bars, as well as of the gun-heads.

Fig. 1



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In tenacity, the small bars greatly surpass the gun-heads, differing about as 7 to 5; but the heads are more uniform than the bars.

The bars cast in the bottom of the mould, under a heavier pressure, do not differ materially from those cast in the upper part of the mould.

A few samples were cut from the square block at the bottom of the cascade, and tested; the results of which are given below:—

Foundry Number of guns.	DENSITY.			TENACITY.	
	Breech square.	Gun-head.	Finished gun.	Breech square.	Head of gun.
1	8.775	8.448	8.749	44923	27972
3	8.850	8.475	8.741	48824	23873
4	8.810	8.468	8.748	48344	26080
11	8.620	8.380	8.331	46706	29863
36	8.773	8.448	8.733	43750	29288
Mean	8.765	8.444	8.740	46509	27415

The breech squares, appear to be superior to the small bars cast separately, but are inferior to the breech samples. A summary of all the mean results, of extra samples, compared with the gun-heads and guns, of the same castings, are given below:—

EXTRA SAMPLES.			GUN-HEADS.		FINISHED GUN.
From what part of castings.	Density.	Tenacity.	Density.	Tenacity.	Density.
32 small bars . . .	8.584	42019	8.497	29859	8.766
5 breech squares . . .	8.765	46509	8.444	27415	8.740
8 extra-breech of guns .	8.823	47690	8.514	31040	8.752

It was observed, that when small spots of tin were visible on the exterior surface of a gun, they abounded most along a longitudinal line, corresponding with the central plane in which the two separate parts of the mould unite.

A few trials were made to ascertain the quality of the metal in the line of these tin spots, compared with the quality in other parts of the gun-head. One sample was cut from the plane of the mould seams, another from the part most remote from that plane, and both near the exterior surface of the head, and a third from its axis. The results are as below:—

Position of samples in the gun-head.	DENSITY.			TENACITY.		
	No. 92.	No. 93.	Mean.	No. 92.	No. 93.	Mean.
In the seam . . .	8.642	8.569	8.605	33341	33191	33266
Between the seams . . .	8.711	8.633	8.672	33926	32351	33138
In centre of head . . .	8.528	8.542	8.535	36867	40229	38548

By these trials, it appears, that the sample taken from the centre of the gun-head, is much stronger than those from the vicinity of the exterior; and that there is no difference between the latter, whether taken from the seam of the mould or remote from it.

Some of the guns having been found defective in the casting, and in boring, were cut up for remelting; which presented an opportunity for examining the interior, by taking samples from several parts of the body of the gun. The opportunity was improved by testing several samples from the 12 pdr. gun No. 28, (the positions of which are shown in Plate X, Fig. 1,) and from the 32 pdr. howitzer, No. 68; the results of which are given in the following table:—

12 PDR. GUN NO. 28.				32 PDR. HOWITZER NO. 68.			
Mark of samples.	Distance above base ring.	Density.	Tenacity.	Mark of samples.	Distance above base ring.	Density.	Tenacity.
	Inches.				Inches.		
28. H.	82.0	8.523	27537	68. H.	79.0	8.487	30690
28. G. P. 1.	76.0	8.569	31147	68. P.	47.0	8.788	38269
G. P. 2.	57.7	8.689	33160	68. T.	23.7	8.808	26428
G. P. 3.	39.0	8.711	36762	68. P.	20.4	8.777	27216
G. P. T.	28.0	8.772	36552	68. T.	7.75	8.828	36762
G. P. 6.	24.3	8.748	32141	68. B. G. P.	Breech	8.835	52192
G. P. 7.	24.3	8.766	23108				
G. P. 8.	24.3	8.752	28518	Small bars of	{ A	8.654	54531
G. P. 4.	20.7	8.756	28989	same casting	{ B	8.572	44630
G. P. 5.	Bottom of bore	8.775	31862				
	Whole gun	8.761					

The most remarkable feature of the above table, is the irregular and heterogeneous character of the results which it exhibits, in samples taken from different parts of the same gun. The gun-head samples, in both, are inferior in density to any other part, but in tenacity, they are both superior to the part in rear of the trunnions. The part about the middle of the gun, above the trunnions, is much stronger than it is in the part immedi-

ately below the trunnions. In one gun the strongest metal is found in the chase; in the other, it is found in the breech. The extreme variations in each gun are as follows:—

No. 28	varies in density from		8.523 to 8.775
No. 68	“ “ “ “		8.487 to 8.808
No. 28	“ “ tenacity “		23108 to 36672
No. 68	“ “ “ “		26428 to 52192

And a small bar cast in the same mould with the latter gives 54531.

The variation of density in different parts of No. 68 is equal to 20 pounds in the cubic foot; and the difference of tenacity, between the lowest sample in one gun and the highest in the other, is as 100 to 236.

By an examination of the results obtained from the heads of all the guns cast, it will appear that the density varies from 8.308 to 8.756, a difference equal to 28 pounds in the cubic foot; and that the tenacity, varies from 23529 to 35484, a difference, in the ratio of 2 to 3. These differences occur in samples taken from the same part of different castings, the gun-head; the part which, in iron cannon, gives a correct measure of the quality of the metal in all parts of the gun.

The extreme variation, among all the samples tested is in density from 8.308 to 8.850, a difference equal to about 34 pounds in the cubic foot; and in tenacity, from 23108 to 54531, a difference, as before stated, as 100 to 236.

The materials used in all these castings were of the same quality, they were melted, cast, and cooled, in the same manner, and were designed to be similarly treated in all respects. The causes why such irregular and unequal results were produced, when the materials used and the treatment of them were apparently equal, are yet to be ascertained.

Some of these differences, may be accounted for, in part. The inferiority of the metal, in rear of the trunnions, appears to be caused by a greater separation of the tin from the copper, in that part of the casting, than occurs in any other part.

Manufacture of Bronze Howitzers at the South Boston Foundry, 1850.

CASTINGS.			METAL USED.						TIME.			TEST OF GUN-HEAD SAMPLES.		FINISHED HOWITZERS.		
Date.	Howitzers.	Foundry. No.	Copper.	BRONZE.		Tin.	Parts of tin in 100 of all.	Total pounds.	In melting.	IN FUSION.		Density.	Tena-city.	Register No.	Density.	Weight.
				Heads.	Chips.					Copper.	Alloy.					
1850									H. M.	H. M.	H. M.					Lbs.
	12 pdr.	11	—	—	—	—	—	—	—	—	—	—	—	62	8.596	217
August 17	mountain howitzers	12	3253	—	—	390	10.71	3643	3. 0	1. 15	3. 45	—	—	63	8.610	219
" 24	"	13	—	—	—	—	—	4482	—	—	—	—	—	64	8.487	216
" 31	"	14	—	4482	—	—	—	—	—	—	—	—	—	65	8.522	216
	"	15	—	—	—	—	—	3679	—	—	—	—	—	66	8.531	217
	"	16	—	3679	—	—	—	—	4. 0	—	4. 30	—	—	67	8.560	219
	"	17	—	—	—	—	—	—	—	—	—	—	—	68	8.524	217
September 7	"	18	—	—	—	—	—	—	—	—	—	—	—	69	8.720	222
	"	19	—	3736	—	—	—	3736	—	—	—	—	—	70	8.712	222
	"	20	—	—	—	—	—	—	—	—	—	—	—	71	8.646	222
" 14	"	21	—	—	—	—	—	—	—	—	—	—	—	72	8.624	219
	"	22	—	3831	—	—	—	3831	3. 30	—	4. 0	—	—	73	8.683	221
	"	23	—	—	—	—	—	—	—	—	—	8.287	24728	74	8.534	219
" 21	"	24	—	—	—	—	—	3683	—	—	—	8.212	23570	75	8.430	215
	"	25	—	3683	—	—	—	—	—	—	—	8.226	25943	76	8.514	217
	"	26	—	—	—	—	—	—	—	—	—	8.314	23803	77	8.592	218
October 10	"	27	—	—	—	—	—	—	—	—	—	7.986	17761	78	8.195	209
	"	28	—	3806	—	—	—	3806	3. 15	—	4. 45	8.351	28995	79	8.551	218
	"	29	—	—	—	—	—	—	—	—	—	8.538	23722	80	8.752	224
" 15	"	30	—	—	—	—	—	—	—	—	—	8.490	35578	81	8.733	223
	"	31	—	3716	—	—	—	3716	3. 30	—	4. 00	8.485	31444	82	8.746	224
" 19	"	32	—	—	—	—	—	—	—	—	—	8.497	30286	83	8.773	224
	"	33	—	—	—	—	—	—	—	—	—	8.416	23149	84	8.709	222
	"	34	—	3700	—	—	—	3700	4. 0	—	4. 0	8.439	23149	85	8.747	224
Mean	—	—	—	—	—	—	—	—	—	—	—	8.353	26011	—	8.604	219½

Three howitzers were cast at each melting, except that of August 24th, when guns for the merchant service were cast, and that of October 19th, when the order was completed. In numbers 24 to 34, inclusive, the castings are numbered in the order in which they were made. No samples were taken from the gun-heads of numbers 11 to 22.

Small bars were cast at the same time with each howitzer, in the same mould, the positions of which, and of the gun-head samples, are exhibited in the annexed sketch. (See Fig. 2, Plate X.) The tests of the bars are given in the following table:—

Number of samples.	Density.	Tenacity.
12	8.736	49667
13	8.705	49456
14	8.623	50088
15	8.586	49562
16	8.613	49141
17	8.602	48841
18	8.819	53485
19	8.694	47878
20	8.789	47562
21	8.734	49877
22	8.804	55980
Mean	8.700	50140
23	8.840	55980
24	8.766	50719
25	8.654	44090
26	8.757	48614
27	8.686	50973
28	8.823	52330
29	8.846	56786
30	8.896	53798
31	8.829	52902
32	8.832	56360
33	8.852	54015
34	8.824	50468
Mean from same	8.800	52253
castings	8.353	26011
Bars	8.606	—
Heads		
Guns		

When casting the howitzers numbered 27, 28 and 29, a trial was made to ascertain what variations, in the quality of the metal, were caused by casting it into the moulds at different temperatures. For this purpose, the metal was raised to a very high temperature in the furnace, and the whole of it was discharged from the furnace into a crane ladle, at once. The howitzer No. 27 was cast immediately afterwards, while the metal was at its highest temperature; No. 28 was cast from the same ladle, fifteen minutes later; and No. 29, at fourteen minutes after No. 28. When the last howitzer was cast the metal appeared *dull*, and as low in temperature as it could well be and retain sufficient liquidity for casting. The surface of the metal, while it remained in the ladle, was kept well covered with charcoal, to prevent the oxidation and escape of the tin.

In making these three castings, all due precautions were taken to insure an equality of all attending circumstances, excepting that of temperature of metal, at the time of casting. The metal was all poured from the same vessel, at different periods of time, into similar moulds, and each left to cool down in the same manner.

Test bars were cast within the gun-moulds, as usual in other howitzers; and similar bars were cast at the same times, and at the same temperatures, in separate moulds. The results of the tests of the various samples, obtained from these three castings, are given in the following tables:—

Time of metal in the ladle. Minutes.	Temperature of metal at casting.	No. of gun.	DENSITY.					
			GUN-HEADS.			Entire gun.	SMALL BARS.	
			H. L.	H. S.	Mean.		In gun mould B.	Separate mould B. S.
0	Highest	27	7.978	7.995	7.986	8.195	8.686	8.554
15	Mean	28	8.345	8.357	8.351	8.551	8.823	8.447
29	Lowest	29	8.519	8.558	8.538	8.752	8.846	8.376
TENACITY.								
0	Highest	27	17698	17825	17761	—	50973	31132
15	Mean	28	29216	28775	28995	—	52330	28153
29	Lowest	29	23381	24064	23722	—	56786	28082

In casting howitzer No. 30, small test bars were cast in separate moulds; one of which was of cast-iron, to ascertain the effect of very sudden cooling,

and the others were of clay, similar to the gun-mould. The tests of all the samples from this casting were as follows:—

		Density.	Tenacity.
Small bars, cast	{ iron mould	8.953	37688
separately, in	{ clay mould	8.313	25783
Small bar, cast in gun-mould	.	8.896	53798
Gun-head samples	. . .	8.490	35578
Finished howitzer	. . .	8.733	

The above tables exhibit an extraordinary diversity of results, which are quite surprising when we bear in mind that all of them are given by the same metal, contained in the same vessel in one liquid mass, until poured from it, at different periods of time, into similar, but separate moulds. They show the great influence which the temperature of the metal, at the time of casting it, has upon the quality of the castings, and the importance of ascertaining what temperature is most suitable for obtaining the best results.

In casting the three howitzers at different temperatures, the moulds were all filled full and evenly at the top. In No. 27, cast at the highest temperature, the liquid metal sank down gradually in the mould, for a few minutes after casting, receding about one and a half inches below its original height. Soon after, the surface presented an appearance of ebullition, as of gases escaping, and expelling the more fluid portions of the alloy, which rose and overflowed the top of the mould. The exuded metal congealed in forms similar to that of *cinder*, or lava, from an iron smelting furnace. It was of much lighter color, a dirty white, containing a much larger portion of tin than the mass of the casting. The entire casting, when cold, was an inch longer than its mould, having elongated itself about two and a half inches beyond the point of its greatest depression, which it attained a few minutes after casting. The mass of the casting appeared to be filled with very minute vesicular cavities, appearing everywhere in the turned or bored surfaces. The density of the gun-head samples, and of the entire gun, were exceedingly low, the former being 7.986, and the latter 8.195. The inferior tenacity is equally remarkable, being only 17761.

The howitzer No. 28, cast at an intermediate temperature, when it had become cold, was $1\frac{9}{10}$ inches shorter than its mould, and presented a plane surface at the upper end. No. 29 exhibited a concave surface, one and a

half inches deep at the centre, at which point the casting was three inches shorter than the mould.

The density of the gun-heads of the entire gun, and of the small bars cast in gun-moulds, increases as the temperature at casting diminishes; and the tenacity appears to follow the same law, except in the gun-heads cast at a low temperature, which are inferior to those cast at the intermediate temperature. It thus appears that a high temperature at casting, is injurious to the quality of the metal.

The extreme variations among the tested samples, taken from different parts, of these three castings, all made from the same mass of melted metal, are, in density, from 7.978 to 8.846, a difference equal to 54 pounds in the cubic foot; and in tenacity, they vary from 17698 to 56786, a difference of more than 3 to 1. It may be supposed that the liquid mass of metal was homogeneous while in the ladle; and if it was so, then these extreme variations, in the solid castings, were caused solely by differences in the manner of cooling. These differences consist, 1st., in lessening the temperature while in the ladle: 2d., cooling in a large mass: 3d., cooling in a small mass, in close proximity with the large mass; and 4th., cooling in a small mass, in a separate mould.

Howitzer No. 30 was cast at the usual mean temperature; and small bars were cast separately at the same time, in an iron, and in a clay mould. That cast in the iron mould, was of an extreme high density, 8.953, an excess, over that cast in the clay mould, equal to 40 pounds in the cubic foot; and as compared with the gun-head of No. 27, cast at the highest temperature, the difference is equal to 61 pounds per foot. The tenacity of the bar, cast in the iron mould, exceeds that cast in clay, about as 3 to 2.

The small bars cast in the gun-moulds greatly surpass the gun-heads, and similar bars cast in separate moulds. The mean tests of the gun-heads, and of the bars cast with them in the same moulds, are as follows, viz:—

	Density.	Tenacity.
12 gun-head samples . . .	8.353	26011
12 small bars, cast with guns	8.800	52253

This great superiority of the small bars over the gun-heads, may be attributed to their cooling rapidly at first, and until they become solid, and to their subsequent cooling being then retarded, by the adjacent liquid mass of metal in the gun-head. The bar is in contact at one end with the gun-

head, and any contraction which may occur in it, after its solidification, is supplied by the liquid metal in the head, with a force due to its column of pressure. This fills all cavities, and gives compactness to the bar. The heat in the massive head which joins the bar, controls and prolongs its cooling. The small bars, cast in separate moulds, are cooled rapidly from first to last, and the cavities formed in their contraction are not supplied from any separate source. To these circumstances we must attribute their inferiority, to the bars cast in the gun-moulds.

It is the opinion of some chemists, that melted bronze separates into two or more distinct alloys while cooling; each combining different proportions of copper and tin, and forming separate and definite chemical compounds. One of them, combining the largest portion of copper with the least portion of tin, will form an alloy having a higher melting point, than another which combines a larger portion of tin. The former will crystallize and become solid, while the latter, being more fusible, will remain a longer time liquid. The correctness of this opinion appears to be sustained by the phenomena attending the casting and the cooling of howitzer No. 27. The alloy, which exuded at the upper surface of that casting, was evidently quite different from the remaining mass; it being of a much lighter color and containing a much larger proportion of tin. Its separation appears to have been caused by the gases which are generated in the mould at casting. As these gases cannot escape through the compact mould, they ascend through the spaces made vacant by the contractions in the crystallized mass, and force along with them, and expel, the more fusible alloy. If the copper and tin united in one chemical compound only, all parts of the alloy would be equally fusible, and would all crystallize at the same temperature; and if the two metals formed a mechanical mixture only, the tin, which crystallizes at a low temperature, would remain liquid a long time after the copper had become solid, and the expelled metal would in that case consist of tin alone.

This division of the copper and tin, into two or more separate alloys, probably occurs at some definite temperatures: one division may occur in the liquid mass, and another after the temperature falls below the melting point of copper. The latter probably occurs in all large castings; for on a close examination of any gun casting, some trace of this whitish alloy will be found in some parts of it. That such a division may occur in the liquid

mass appears evident from the fact, that a portion of the liquid bronze will pass through a porous vessel as through a sieve, or strainer, while another portion will remain within the vessel. The former is the lighter colored, and more fusible alloy; and the latter is the less fusible, and is that which forms the mass of the gun castings. It thus appears, that we may separate the more fusible alloy from that which is less fusible, by sifting while both are liquid.

It is found, that some portion of the metal will always penetrate the gun-mould, and that this portion always contains a large proportion of tin. Moulds made of porous materials, or which are imperfectly rammed, will absorb larger portions of the metal than those which are more compact; but no moulds, however compact, made of the best German clay, will resist the penetration of some portion of the metal. It is not improbable, that the proportion of the two metals which form the alloy found mixed in the gun-moulds, is determined by the temperature at casting, or by the compactness, or porosity of the moulds, or perhaps a combination of both causes.

The excessive heat at which howitzer No. 27 was cast, does not appear to have impaired the quality of the small bars cast at the same time. In density and tenacity, the bar cast within the gun-mould is a little inferior, and the other bar, cast in a separate mould, is a little superior, to the similar bars cast from the same melting, at lower temperatures.

It appears, therefore, that the injurious consequences of casting at a high temperature, are limited to castings of a large mass.

The appearance of the samples, after testing, differs as widely as do the numbers in the tables which represent their densities and tenacities. The small bars of the higher qualities, such as are cast in the gun-mould, appear to be homogeneous. The surface of fracture appears uniform in color and texture, having a fine granular and brilliant aspect, and often presents a finely reticulated or sieve-like appearance. The samples of the lower qualities, such as are obtained from the gun-heads, present a heterogeneous appearance, like a mixture of different substances, with dull blotches of different colors; an open, porous, conglomerate, without any apparent cohesive bond of union.

The changes of form which the two classes of samples undergo, while under tensile strain, were singularly variant. The small bars of the first class endure a much greater extension in length before breaking, than the

weaker samples. The elongation was accurately measured in eight samples of the former, and in nineteen of the latter. The mean extension, in parts of the entire measured length, and the mean density and tenacity of the same samples, were as follows:—

	Extension.	Density.	Tenacity.
8 Small bars	.27	8.648	48613
11 Gun-head samples	.08	8.455	27997

The contractions in diameters were in similar proportions.

The forms of the samples, after being strained, were very different. The weaker samples preserved their original circular form in all parts, while many of the stronger samples were much distorted: some parts of the surface of the cylinder were changed into plane surfaces, resembling in shape the flat faces of crystals. The distorted forms exhibited, seemed to indicate that the mass of the solid had struggled to resist the increasing strain it was enduring, until all its particles had become united in forms resembling the primitive crystal. Such changes of form occurred, in samples of the greatest density, tenacity, and homogeneity.

The greatest defects in the quality of bronze guns appear to arise from their defective homogeneity, caused by a division of the alloy. Defects of this character exist in a greater or less degree in all bronze guns; none are entirely exempt from them; and we may receive it as a safe general rule, that the quality of the metal is as its homogeneity. Defective homogeneity may not be visible on the surface of guns recently finished, for the white alloy, when minutely divided, disappears under the finishing tools, being covered over by the more tenacious and ductile reddish alloy. Small vesicular cavities are concealed in the same manner by the turning tools. If the guns are exposed to the weather in the open air a few weeks, the white alloy and the cavities will reappear. They may be developed in freshly finished surfaces by the application of acids. Undiluted nitric acid, remaining on the surface one minute and washed off quickly after with clean water and then with lye, or muriatic acid diluted with one-third water, acting five or six minutes, will expose the defective homogeneity.

On a general resurvey of the results obtained from all the samples tested, the most striking feature exhibited is that of their great diversity in density and strength, and for which no obvious or satisfactory cause is seen or can be assigned. In grouping together the tested samples, divided into

classes, according to the manner of casting and cooling, the most interesting features exhibited are, the great superiority over all others of the small bars cast within the gun-moulds, and the extraordinary effects caused by differences in the temperature of the metal at the time of casting.

The causes of the superiority of the small bars appear to be, that they are suddenly cooled from the liquid to the solid, and are thereby not allowed a sufficient time for a division of the alloys into separate compounds; and, that the small bars are soon after partially reheated, and then are cooled very slowly. The cooling of these bars from the liquid to the solid is similar to those cast in separate moulds: they are both cooled suddenly thus far, but the cooling after this differs greatly. Those in the separate moulds continue uninterruptedly in rapid cooling until quite cold, while those in the gun-mould are first reheated nearly to the melting point, and cool very slowly. They are both nearly equal in homogeneity, but they differ greatly in color, density, and strength; and this difference appears to be caused, solely, by the manner of cooling. The effect on the quality of the metal caused by these different methods of cooling bronze, appears to be the reverse of that which occurs in cooling iron, by the same methods; for the qualities of the latter are impaired by annealing.

If the quality of metal, in the entire mass of the gun, could be made equal to that which we find uniformly in these small bars, there would remain little or nothing further to be desired in the improvement of bronze guns; and it is worthy of consideration whether means may not be devised, by which we may approach, if we may not fully attain, such a degree of improvement. The large mass of which a gun consists, cannot be cooled from the liquid to the solid so suddenly as the small bars; but the cooling may be greatly accelerated, and I suggest the following, as among the methods which may be tried for this purpose.

Let the exterior case of the mould be made of cast iron; its interior to conform in shape to the exterior of the gun, but a little larger in its lateral dimensions, so as to allow a thin lining of clay, or other suitable material, to be placed on the interior of the case. Iron being a good conductor of heat, and the lining of clay being very thin, the heat in the liquid bronze would pass off very rapidly, if the exterior of the metal case be kept cool by a free circulation of air over it. The heat would escape first, from that part of the metal which is in immediate contact with the mould, and at a later period,

from the centre parts of the casting. The exterior of the casting would thus immediately fall to a lower temperature than the interior, and would continue so, during the whole process of cooling, down to the last moment when the centre became cold. In such a process of cooling, there would be a period of time when the exterior would be solid while the interior would be liquid. This inequality of temperature between the exterior and interior, during the whole period of cooling, would tend to cause cavities in the interior, a division of the alloys, and heterogeneity in the mass of the casting. In order to prevent these evils, we may apply the invention of Lieut. Rodman for cooling the interior of guns, by circulating a stream of water through a hollow core, placed within the gun-mould previous to casting. By this method, the heat may be carried off as rapidly from the interior as from the exterior, and an equality of temperature in all parts may be maintained.

The hollow core may be so arranged that the water shall be discharged from it horizontally through the lower part of the gun-head, near its junction with the muzzle of the gun.

By this method, the metal in the head will remain unaffected by the circulating water, and will continue liquid until after the body has become solid; thus securing a fountain of liquid bronze, which, by its own gravitation, will supply the void spaces caused by the contractions in the solid.

In order to cool the gun in the same manner as the small bars within the gun-mould are cooled, this accelerating process must be discontinued directly after the casting has become solid, and the cooling thereafter should be retarded. This may be effected by stopping the circulation of water through the interior of the core; and, by covering closely the pit which contains the casting, the circulation of air on the exterior of the mass will be prevented.

The great difference in the quality of the bronze, cast in the small bars of the same bulk, from the same melting, at the same time in similar moulds, indicates that the metal undergoes a change in texture after it has become solid. Sudden cooling is evidently most effective in producing homogeneity in the casting, whether it be continued to the end, or be checked immediately after solidification occurs. Reheating the solid soon after it is formed, and prolonged cooling afterwards, greatly improves the tenacity of the metal, as is shown by the strength of all the separate bars cooled in

this manner within the gun-mould. It is conjectured that the same effect would follow, if the reheating occurred after the bar had become quite cold. It would be interesting to ascertain the effect of reheating bronze which had been first cooled suddenly, and also such as had been cooled slowly; and then, after reheating to an intense red heat without changing the form of the solid, to cool either, and each, both suddenly and slowly. Material changes of texture, color, and strength, would no doubt be effected by such reheating and cooling. Bars, which were similar in all their qualities before being submitted to this treatment, would exhibit various qualities afterwards. Some of these changes would be beneficial, and others the reverse. Experiments which would determine the character of these changes, and the prevailing law which governs in such cases, may be conveniently made with small bars; but the law which may be found to prevail in these, would not be reliable, as a safe guide, in casting guns. The results obtained from such trials, with small bars, would, however, serve to indicate such a treatment of the metal, as would be most likely to produce beneficial results in castings of a large bulk.

The singular changes which are effected in the character of the solid bronze, by differences of temperature in the liquid metal, at the time of casting, renders it important that we should possess some means of measuring its temperature, relatively at least, with accuracy and facility. Instruments which have been devised for measuring such high temperatures, are either unreliable for accuracy, or require so long a time to complete the observation, as renders them unfit for this purpose. To be practically useful, an instrument for this purpose should be capable of determining the result in a very short time, a minute or two, at most.

Since casting these bronze guns, I have endeavored to ascertain the relative temperature of liquid iron, at the time of casting, by pouring a small quantity of iron into a much larger quantity of water, and by ascertaining the heat imparted to the latter by the former. A vessel, to contain about 45 pounds of water, made of very thick, dry, oak staves, and varnished in the interior, was used. A hole was made in one end of the vessel, through which the liquid was poured, and a thermometer was passed. The weight and the temperature of the water are first accurately determined; then the liquid metal is cast into the water, and the aperture is immediately closed by a close-fitting valve, which prevents any steam or vapor escaping from

the vessel. In a short time, the iron and the water become of an equal temperature; the thermometer then indicates the heat acquired by the latter. The weight, of the water, being multiplied by its increased temperature and the product divided by the weight of the iron, the quotient gives the measure of the relative temperature of the metal when cast.

The following table gives the particulars of the few trials made:--

	WEIGHT OF		TEMPERATURE OF WATER.			Relative temperature of liquid iron.
	Water. lbs. ozs.	Iron. lbs. ozs.	Before casting.	After casting.	Difference.	
Common castings	43. 9	2. 3	66°	89°	23°	458
	42. 12	3. 5	87	122	35	452
	42. 7	0. 12 $\frac{3}{8}$	66	73 $\frac{1}{2}$	7 $\frac{1}{2}$	414
High heat . . .	43. 10	0. 5 $\frac{3}{4}$	66	70	4	485
Low heat . . .	45. 0	1. 7	78	91 $\frac{1}{2}$	13 $\frac{1}{2}$	423
Solid casting . .	44. 4	1. 3	70	78	8	301

These trials are not sufficiently varied, nor were the instruments used for determining temperatures and weight sufficiently delicate, to give to the result an accurate and reliable character. On the other hand, the results do not present anything to deter us from repeating trials of the same character, with means better adapted to the purpose, for determining the relative temperature of liquid bronze. The first two, and last three, of the trials accord very well with what might be expected under the circumstances. The third trial gives an incorrect result; the heat of the iron in that trial, appeared to be equal to either of the preceding. The iron cast in the fourth trial was at a maximum temperature; and at the fifth trial at a minimum temperature; and the results accord with this condition.

The general results which are exhibited in this report, on the qualities of bronze as they are found in guns, are mostly of a negative character. They expose defects in density and strength, develop the heterogeneous texture of the metal in different parts of the same gun, and show the irregularity, and uncertainty of quality, which attends the casting of all guns, although made from similar materials, treated in like manner. Such of the results as are uniformly satisfactory, are obtained, not from any part of the guns, but from other castings, made in other forms. Such a detail of unsatisfactory results should be followed by a statement of the appropriate remedies for such deficiencies, with suggestions for such treatment of

the materials, as would effect the desired reform. As a reason why this is not now attempted, it is proper to say, that this was the first of my experience in the manufacture of bronze guns. It had never before become my official duty to attend to this branch of Ordnance Service. The occasion, and its limited time and opportunities, permitted nothing more than preliminary inquiry, and observation of the methods usually practised; and, such investigations as would ascertain the results actually produced by those methods. If time and opportunity had permitted a more extensive research, such preliminary investigations must have first been made, in order to discover what deficiencies, if any, existed; and what remedies were needed. The ascertained facts, which this report exhibits, although they relate chiefly to existing imperfections in the art of manufacturing bronze, will, it is believed, be found useful. They may serve to awaken the attention of those who may, henceforth, be concerned in conducting this branch of service; and to suggest such improved methods of treating the materials, as will ultimately raise our knowledge of the art, to an equality with that which has been attained in the manufacture of iron cannon.

Respectfully submitted,

W. WADE.

DESCRIPTION
OF THE
TESTING MACHINE, HYDROMETER,
AND OTHER
INSTRUMENTS, EMPLOYED IN TESTING METALS.
WITH PLATES.

1854.

THE
INSTRUMENTS
EMPLOYED IN TESTING METALS.
WITH PLATES
AND A
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INSTRUMENTS EMPLOYED IN TESTING METALS.

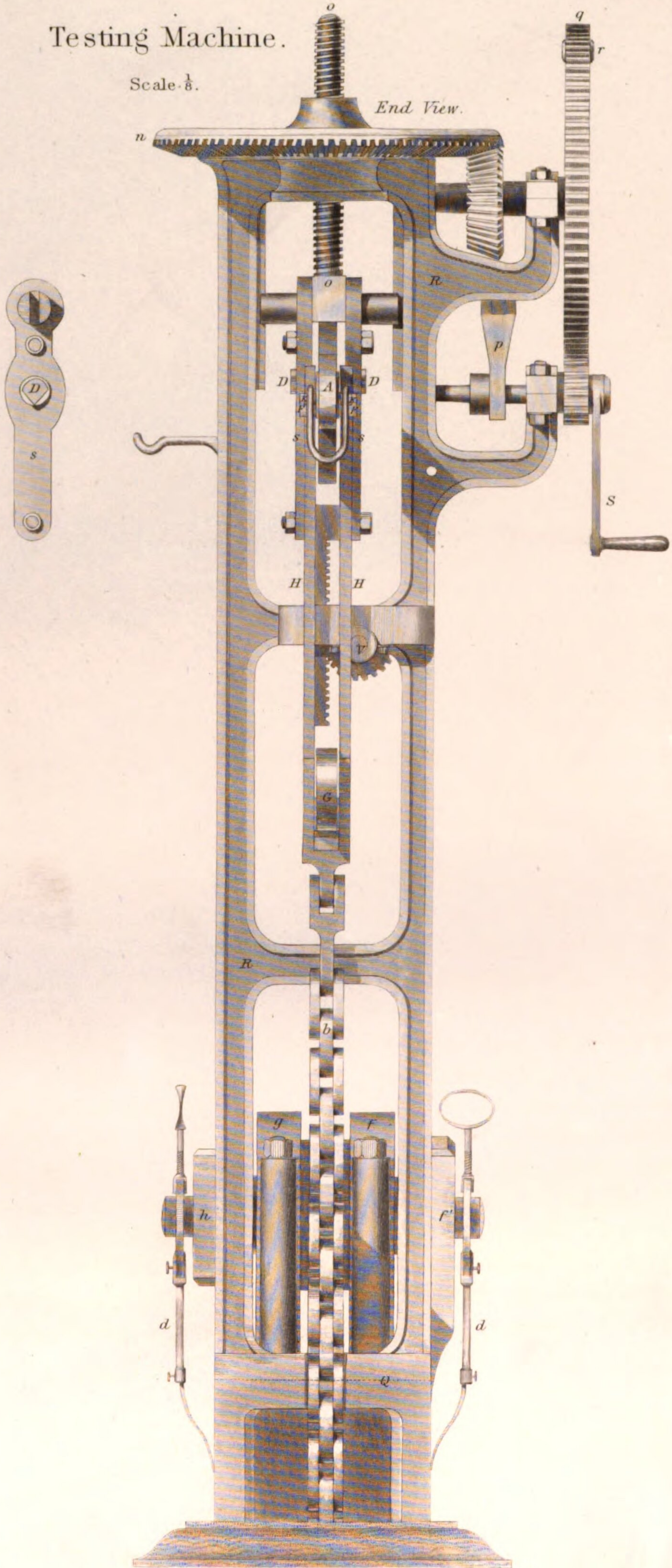
WITH PLATES.

1854.

Testing Machine.

Scale $\frac{1}{8}$.

End View.



DESCRIPTION

OF THE

TESTING MACHINE, HYDROMETER, AND OTHER INSTRUMENTS,
EMPLOYED IN TESTING METALS: WITH PLATES. 1834.

TESTING MACHINE.

PLATE XI, exhibits a side elevation, and PLATE XII, an end view of the machine.

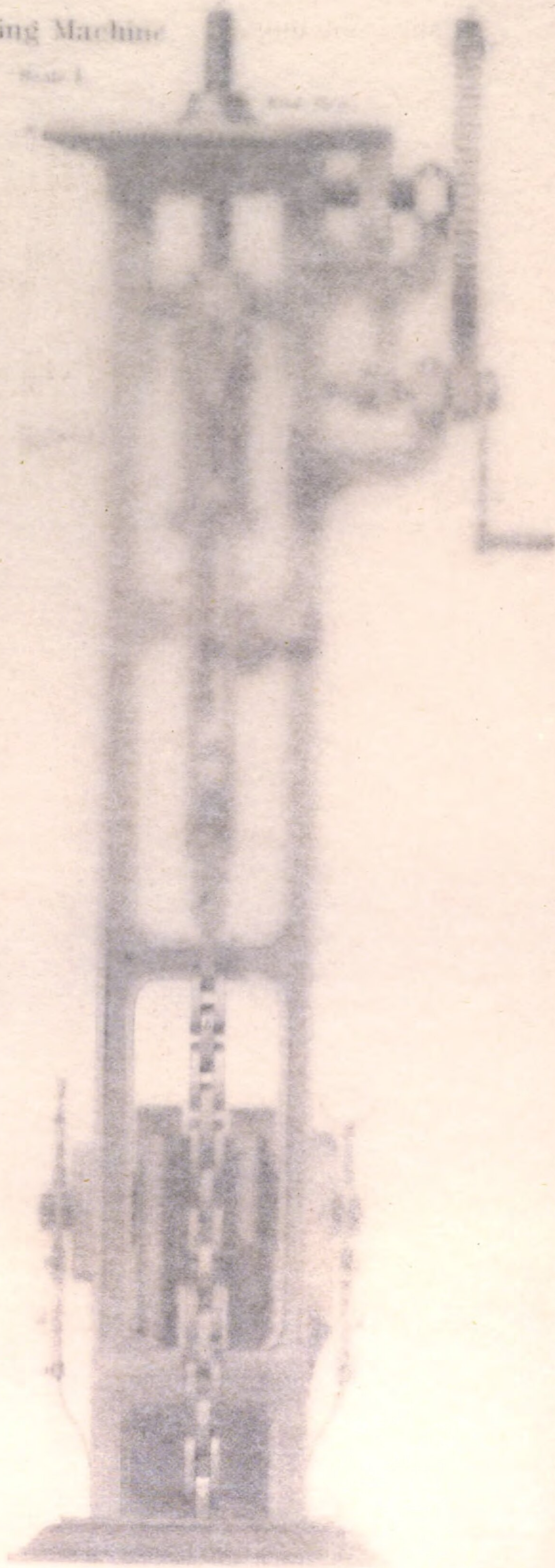
A is the upper or first lever, to which the weights are attached, and to which the power is first applied. All its bearing knife edge pieces are in the same horizontal plane *BC*. Its fulcrum is at *B*, supported by an interior frame *s*, which is attached to the screw *e*, above it. The knife edge *E*, from which the weights are suspended, is seventy-two inches from the fulcrum; and the knife edge *F*, is three inches and six-tenths from the fulcrum; making a proportion between the two arms of the lever, as 20 to 1. The centre of gravity of this lever, is two-tenths of an inch below the plane of its knife edges; and, as the oscillation of the lever is restricted to narrow limits, the centre of gravity can never ascend to the horizontal plane of its fulcrum, nor descend to a point more than .2 inch below it. *G* is the second lever, which is acted upon by the first lever through the stirrup *H*, which connects them. All its knife edges are in the same plane *IK*. Its fulcrum is at *L*, supported by the posts of the bed-piece *Q*. The knife edge *M*, which is linked with the first lever, is sixty inches from the fulcrum, and the knife edge *N*, which acts directly upon the bar under trial, is six inches from the fulcrum: making the power of this lever, 10 to 1. Hence a combination of the two levers gives a proportion of two hundred to one.

The second lever weighs about 500 pounds, and its centre of gravity is

Testing Machine

Scale 1

Scale 2



DESCRIPTION

OF THE

TESTING MACHINE, HYDROMETER, AND OTHER INSTRUMENTS,
EMPLOYED IN TESTING METALS: WITH PLATES. 1854.

TESTING MACHINE.

PLATE XI, exhibits a side elevation, and PLATE XII, an end view of the machine.

A is the upper or first lever, to which the weights are attached, and to which the power is first applied. All its bearing knife edge pivots are in the same horizontal plane *BC*. Its fulcrum is at *D*, supported by an interior frame *s*, which is attached to the screw *o*, above it. The knife edge *E*, from which the weights are suspended, is seventy-two inches from the fulcrum; and the knife edge *F*, is three inches and six-tenths from the fulcrum; making a proportion between the two arms of the lever, as 20 to 1. The centre of gravity of this lever, is two-tenths of an inch below the plane of its knife edges; and, as the oscillation of the lever is restricted to narrow limits, the centre of gravity can never ascend to the horizontal plane of its fulcrum, nor descend to a point more than .2 inch below it. *G* is the second lever, which is acted upon by the first lever through the stirrup *H*, which connects them. All its knife edges are in the same plane *IK*. Its fulcrum is at *L*, supported by the posts of the bed-piece *Q*. The knife edge *M*, which is linked with the first lever, is sixty inches from the fulcrum, and the knife edge *N*, which acts directly upon the bar under trial, is six inches from the fulcrum: making the power of this lever, 10 to 1. Hence a combination of the two levers gives a proportion of two hundred to one.

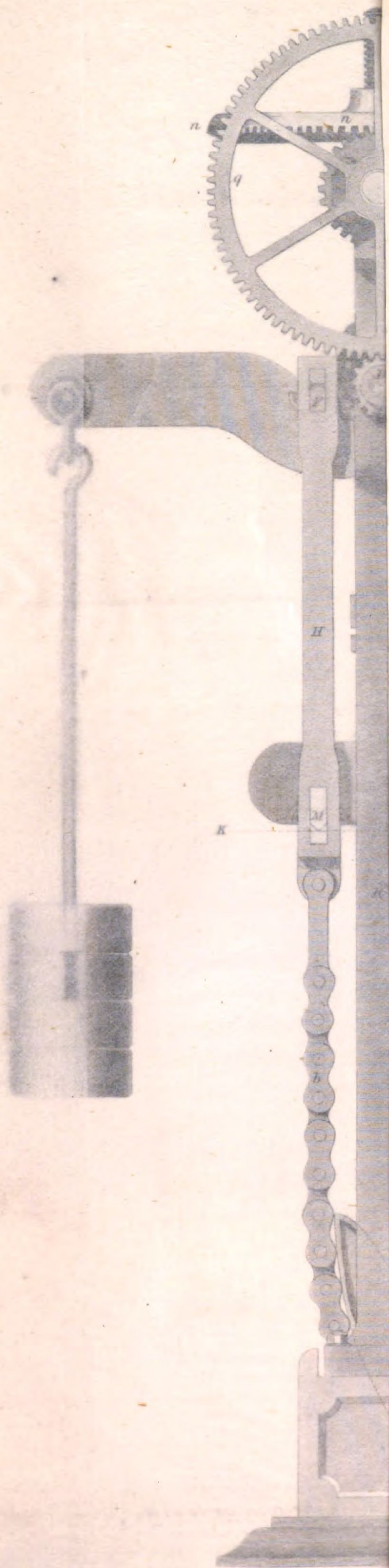
The second lever weighs about 500 pounds, and its centre of gravity is

17.25 inches from its fulcrum. In the extreme movements of the lever, its centre of gravity moves through an arc of about 8° , on a radius of 17.25. This varying position of the centre of gravity, affects the equilibrium of the machine; the effective weight of the lever lessens, as its centre of gravity recedes from the horizontal plane of the fulcrum. To reduce this unavoidable instrumental error to a minimum, such a form is given to the lever, as places its centre of gravity about .3 inch below the plane of its knife edges. The centre of gravity traverses an arc of 8° , one fourth of which is above the level of the fulcrum, and as the bars are broken when the lever is within the upper half of its range of motion, the varying position of the centre of gravity, so far as it affects the breaking weight, is limited to 2° , on either side of the horizontal plane of the fulcrum. The machine is adjusted to an even balance, when the centre of gravity is brought to the intermediate position of 1° above, or below, the horizontal plane. By this arrangement, the effects of the varying position of the centre of gravity, at the straining point of the machine, will never exceed one pound.

A weight of one pound, applied on the platforms of the suspending rod *O*, exerts a force of twenty pounds on the stirrup *H*, and of two hundred pounds at the vertical line *P' P'*, where the strain acts upon the sample.

The rod *O*, suspended from the knife edge *E*, is provided with platforms to receive the weights. The lower platform is hollow, but in its exterior form resembles one of the large weights, and is to be counted as one of them, when the lever is not counterbalanced by weights suspended from its opposite end. The weights used, are of three denominations; viz: half-pounds, five pounds, and twenty-five pounds; each representing strains of 100, 1000, and 5000 pounds. When testing samples in which smaller increments of strain are needed, weights of less than half pound may be used. A weight of one twentieth of a pound, will represent a strain of ten pounds, and 35 grains will represent one pound.

The vertical frame *R* supports the cog-wheel gearing at the top, which is set in motion by the crank *S*. The vertical piece *T* supports the guide *U*, through which the small end of the first lever passes. This guide ascends and descends, evenly with the screw and the fulcrum of the lever, by means of a rack and pinion, at each end of the revolving rod *V*. A mortice through the guide receives the lever and allows it a free motion, to a limited extent. The lever is thus maintained in a position always nearly horizontal,



while it remains free to oscillate on its fulcrum in either direction, as the strain, or the weights, may preponderate. The guide serves, also, to intercept the descent of the weights and the lever, when suddenly released by the breaking of the sample.

The braces *W, W*, secure the stability of the framework of the machine.

X is a stirrup, which rests on the knife edge *N*, of the second lever; the point, at which the power of the machine is exerted upon the bar under strain. The pincers *Y Y*, employed to hold the bar in tensile strains, are attached to the stirrup, by the bolt *Z*, and to the bed-piece, by a bolt through the hole *P*. The sample holders, in all other forms of strain excepting that of torsion, are attached in like manner at one end to the stirrup *X*, and at the other end, to the immovable bed-piece.

a, is the Torsion lever, which is set in motion by the chain *b*, attached to the connecting link *H*. The axis of the torsion lever, at *c*, is hollow, and the bar to be tested passes through it. One end of the bar is held firmly to the pedestal of the bed-frame *f*, and the other end is held to the journal of the torsion lever, at *h*, by means of the keys *e, e*. The axis of the bar is made to coincide with the axis of the torsion lever, by passing the ends of the bar through concentric rings, inserted, in recesses provided for the purpose, before the keys are fixed in their places. *d, d*, are indices, which are attached to the projecting ends of the bar, and adjusted to the zero of the arc beneath, before the strain is commenced. Although one end of the bar is firmly fixed, it will yield a little, by its compression on the keys, and therefore, its angular deflection is determined by the differences between the indices on the arcs. *f* and *g* are pedestals, cast on the bed-piece, within which the journals of the torsion lever revolve. When a bar is placed in the machine for torsion, the lever is placed at its lowest point; but sometimes, the screw ascends to its highest limit before the bar breaks. When this happens, the lever is propped up, the chain is detached, and shortened by removing its upper link; then, on its being again attached, the work is resumed and the strain extended until the bar breaks.

i and *k*, are hollow pedestals, cast on the bed-piece, in which steel bars *l l*, and *m m*, are inserted, which serve as points of support for bars when tested by transverse strain. The supports *l, l*, are 30 inches apart, and *m, m*, are 20 inches apart. The breaking force is applied on the under side of the bar in the middle, and forces it upwards against the supports at the

ends. The deflection of the bar is measured, by inserting a graduated, tapered, metallic scale, between the upper surface of the bed-piece and the under side of the bar holder, directly beneath the forcing line of the latter against the centre of the bar. This space enlarges as the bar bends, and the graduated wedge measures minutely the deflection of the bar, at any stage of its progress.

Twenty turns of the crank *S*, gives one turn to the horizontal wheel *n*, at the top of the frame. A screw nut is cut in the axis of this wheel, through which the screw *o* passes. This wheel, when turned, elevates or depresses the screw, and sets in motion all the movable parts of the machine. Five turns of the wheel move the screw one inch, and this requires one hundred turns of the crank, and gives one-tenth of an inch of motion to the knife edge *N*, where the strain on the sample is exerted. The crank pin, on which the power is first applied, moves a distance of 25 inches at each turn, and 2500 inches, for each tenth of an inch of motion at the straining point of the machine. Such a great power is needed, only when heavy strains are exerted. When beginning a strain, or when lowering down the levers, the pinion on the crank shaft is thrown out of gear, by lifting the latch *p* and withdrawing the shaft. A separate crank pin is then inserted in the spur wheel *g*, at *r*. This change of gearing, gives a velocity six times greater to all the moving parts of the machine.

To adjust the equilibrium of the machine:—The rod *t*, with its platform, is suspended from the knife edge at the large end of the first lever, which is 18 inches from its fulcrum; three of the large weights, of 25 pounds each, are added, and these, with the rod and its weight, make a total of 100 pounds, which is equal to 25 pounds acting at the knife edge *E*, at the opposite end of the lever. The rod *O*, with its three platforms, is then made of such weight as will, when suspended from the knife edge *E*, bring the lever to an even horizontal balance.

When this adjustment is made, the stirrup *X* is in its proper position resting on the knife edge *N*, but no appendages for holding samples are attached to it; and the chain *b*, is detached from the stirrup *H*. A separate weight *u*, of five pounds, is placed on the first lever, and is employed to balance the machine, when different appendages, of various weights, are attached to the stirrup *X*, for holding samples when testing them. The position of this adjusting weight, when the machine is first

Fig. 1.



Fig. 2.

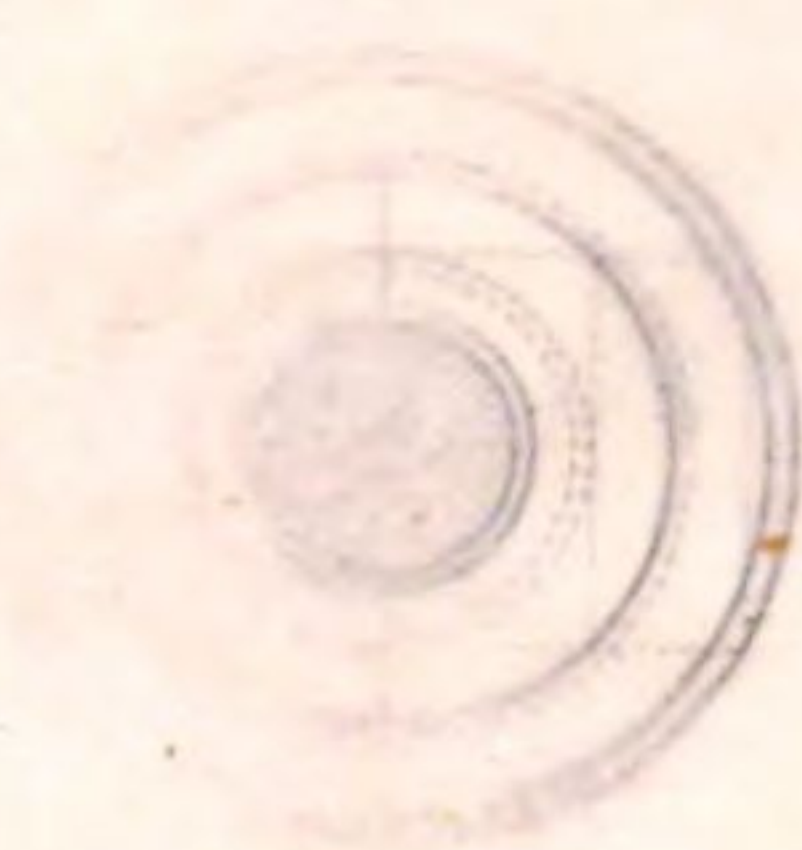


Fig. 3.

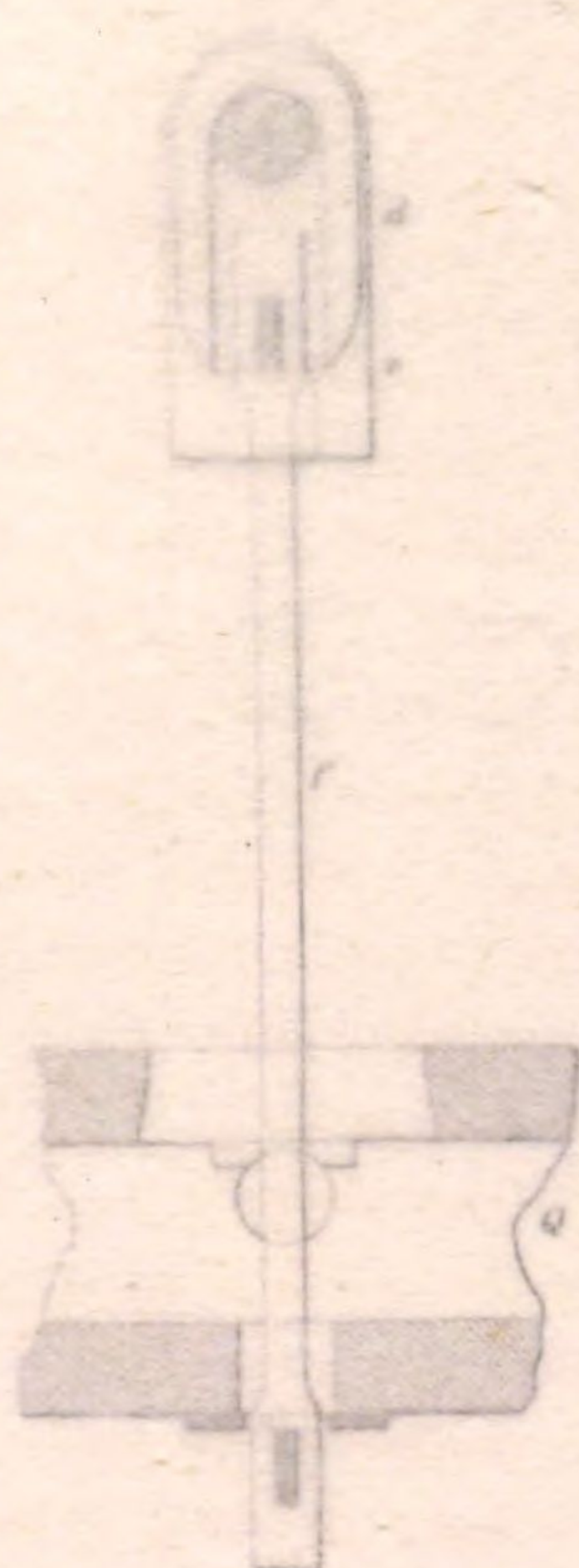
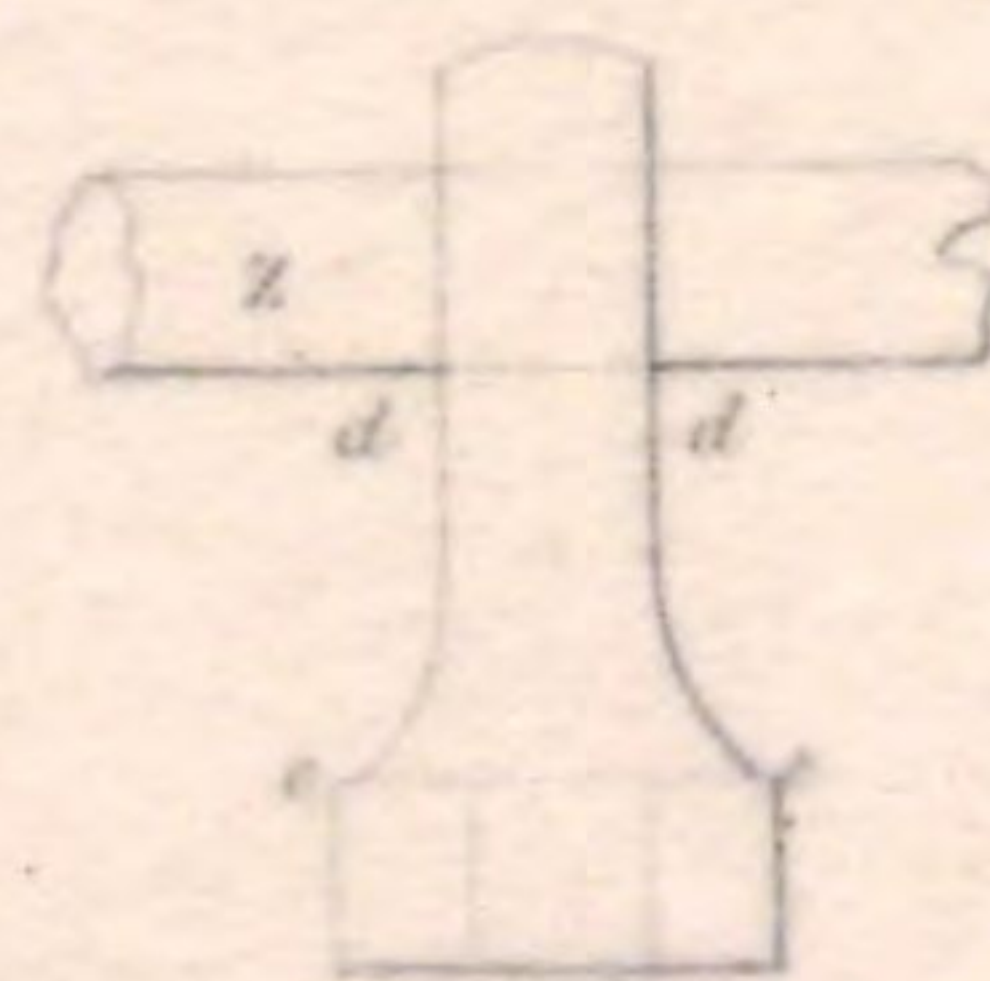


Fig. 5.



Fig. 4.



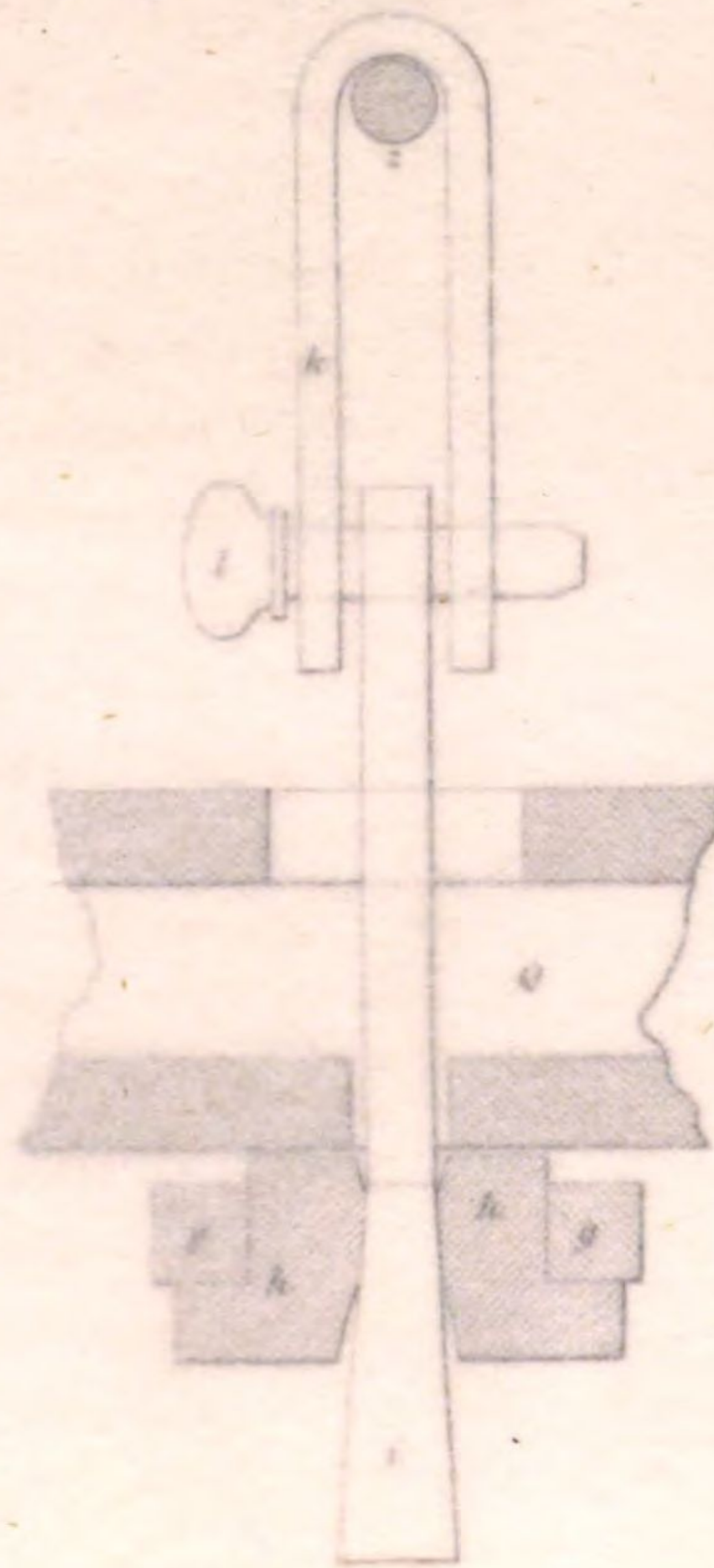
Section.



Section.



Fig. 6.



Scale 8.



Fig. 1.

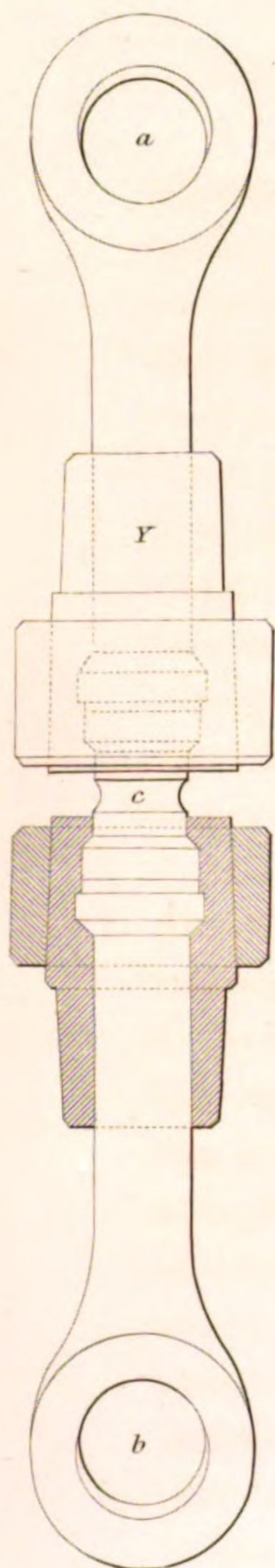
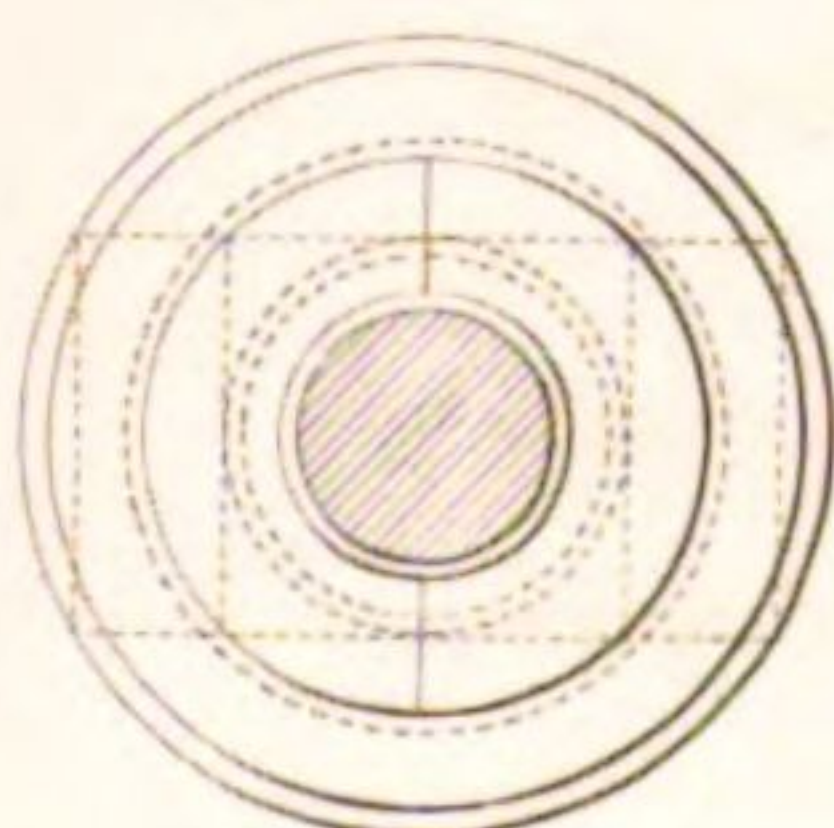


Fig. 2.



Scale $\frac{1}{4}$.

Fig. 3.

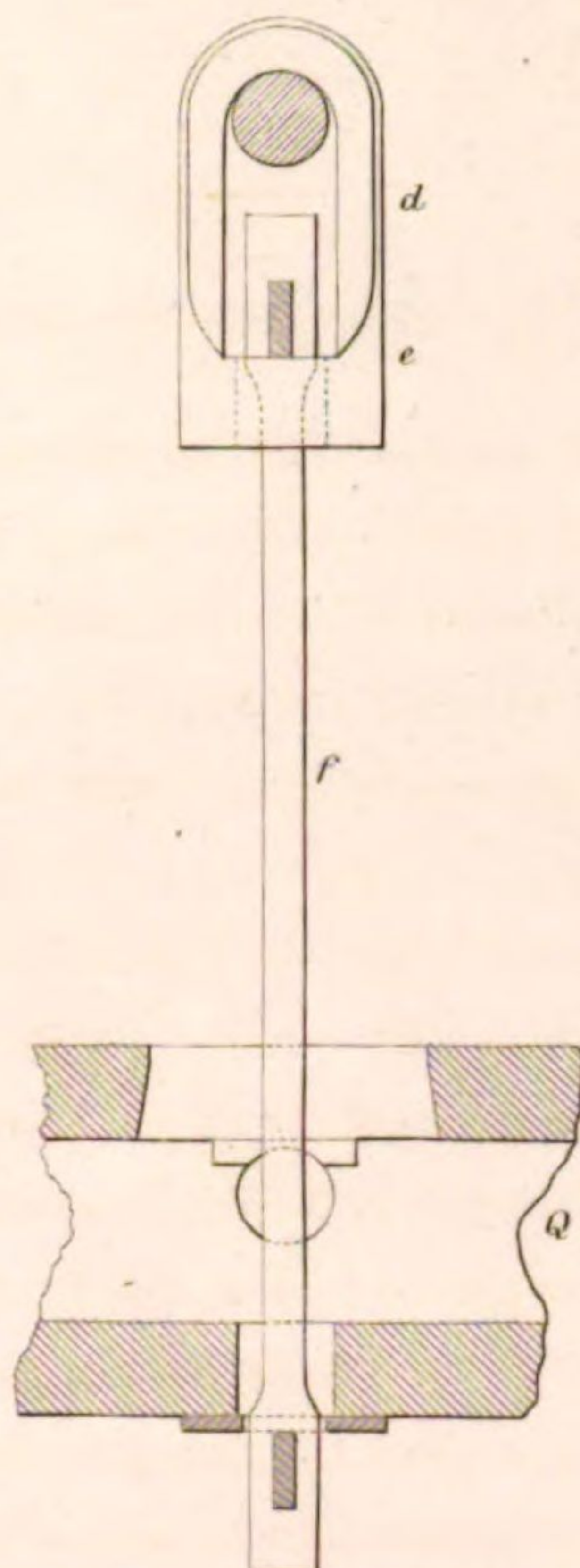
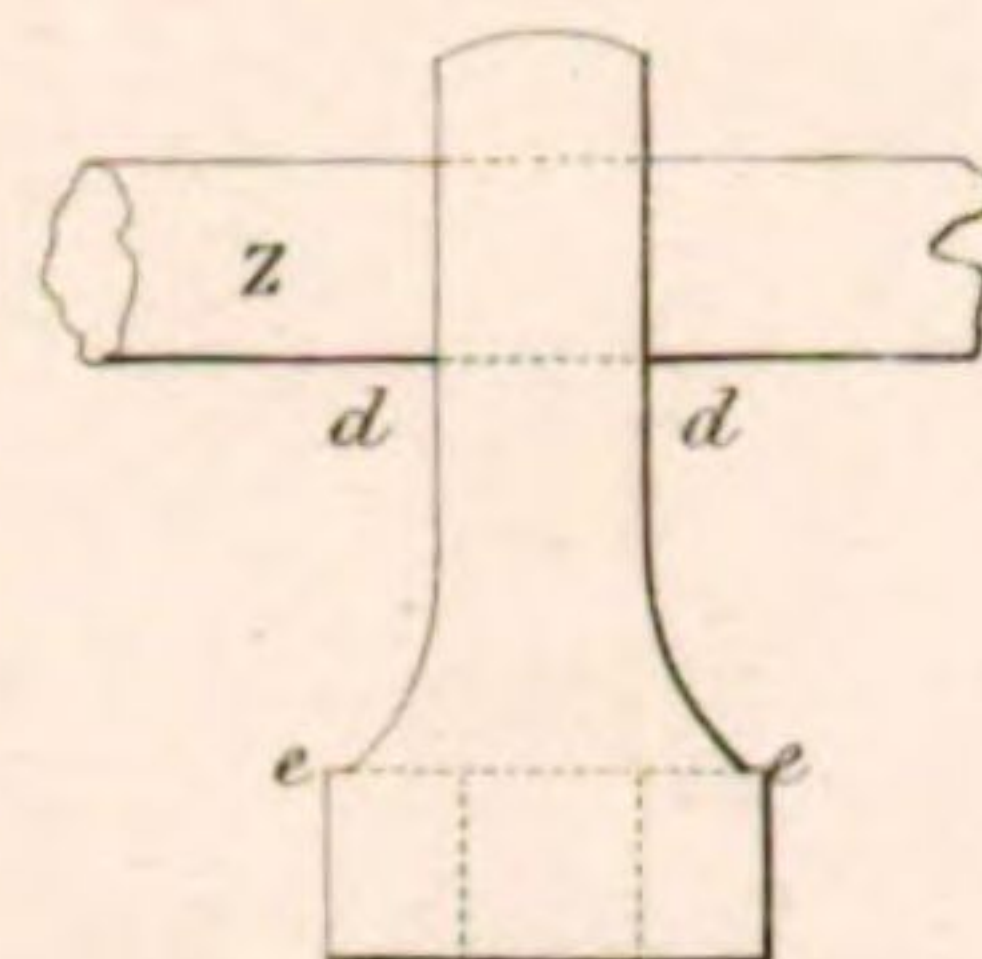
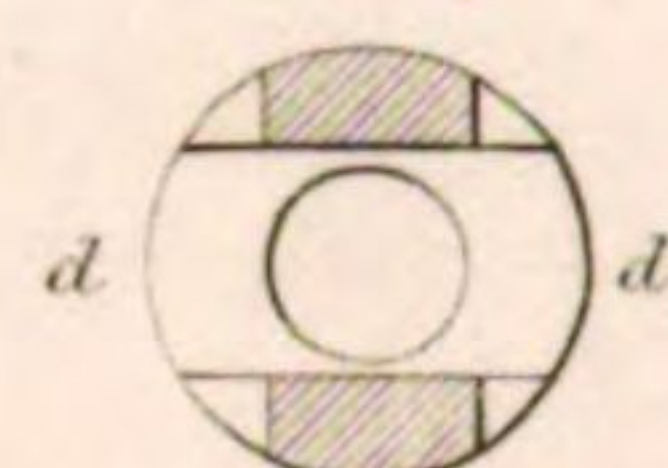


Fig. 4.



Section.



Section.

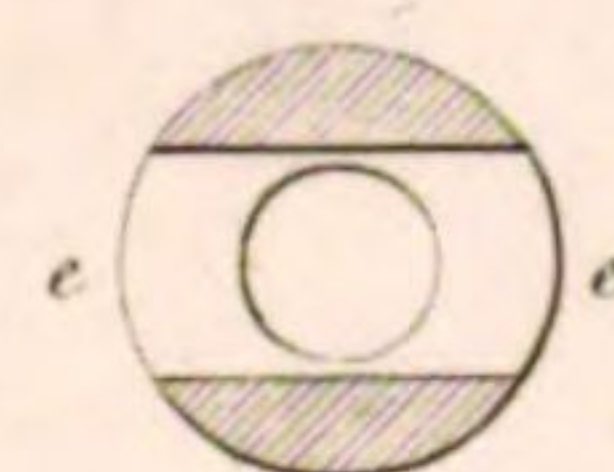


Fig. 5.

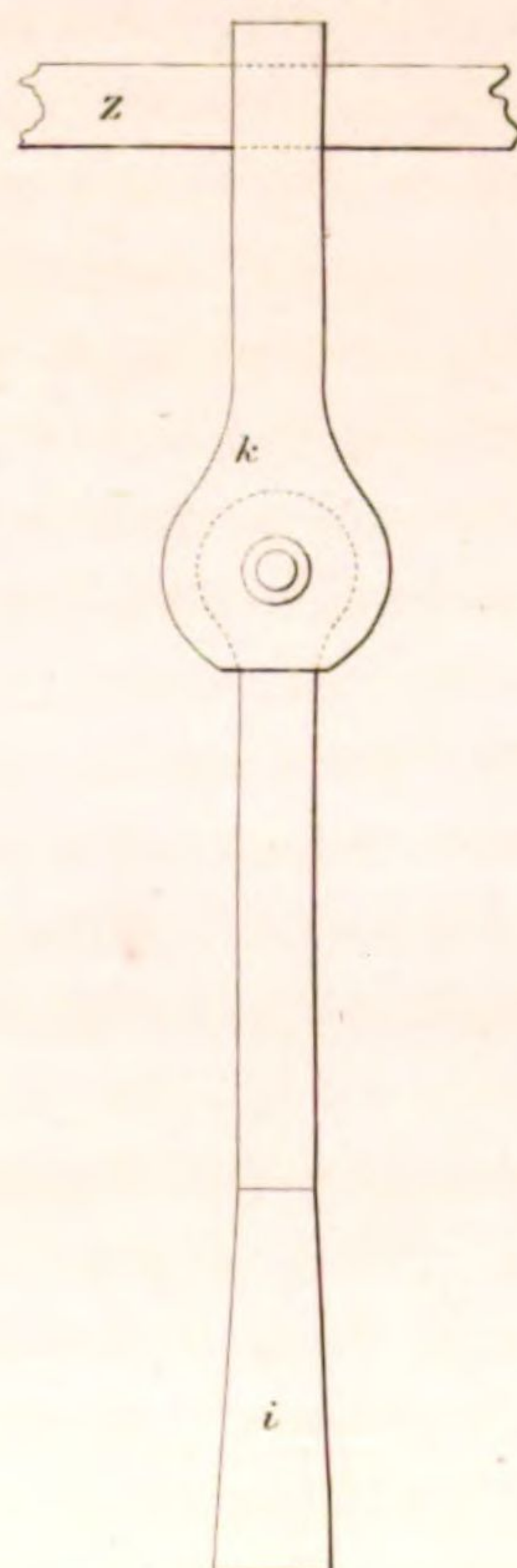
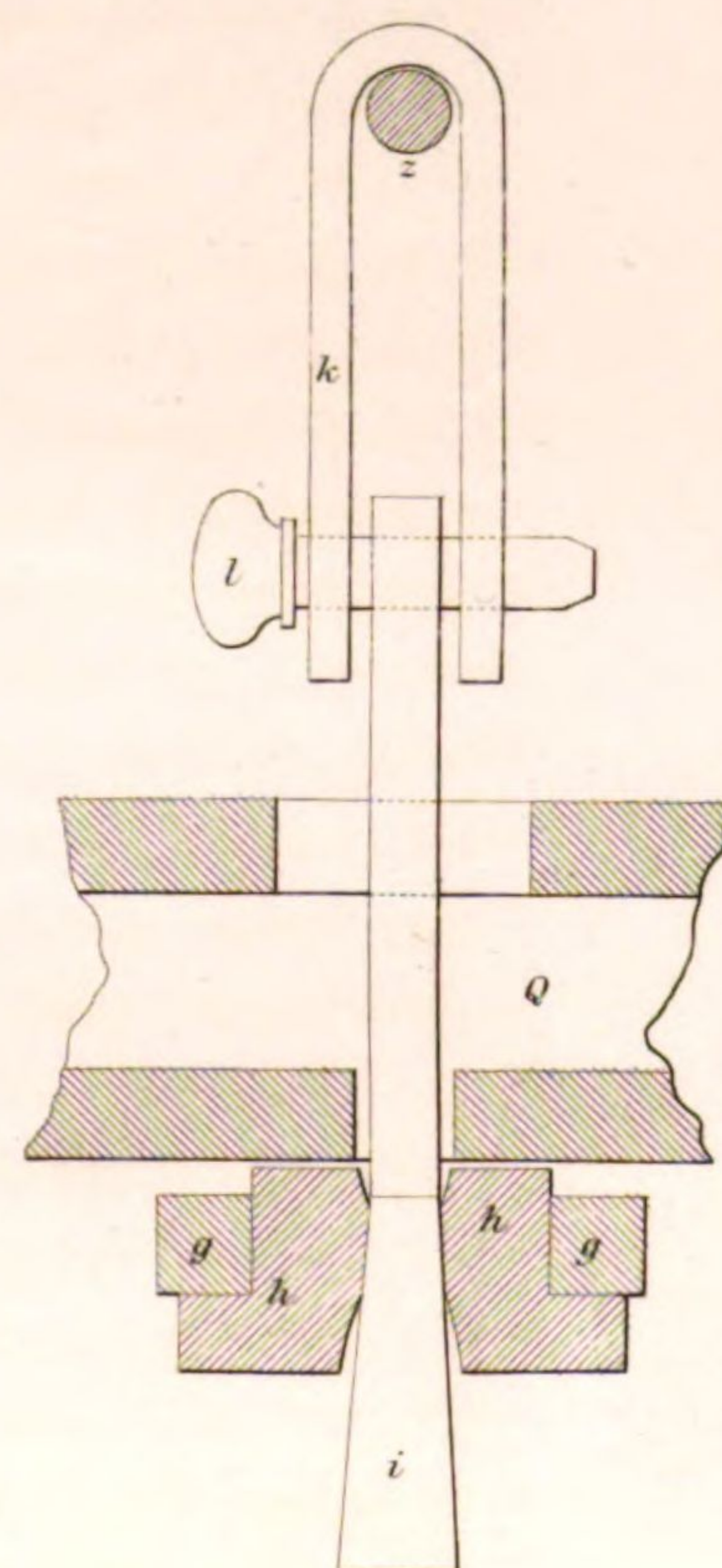
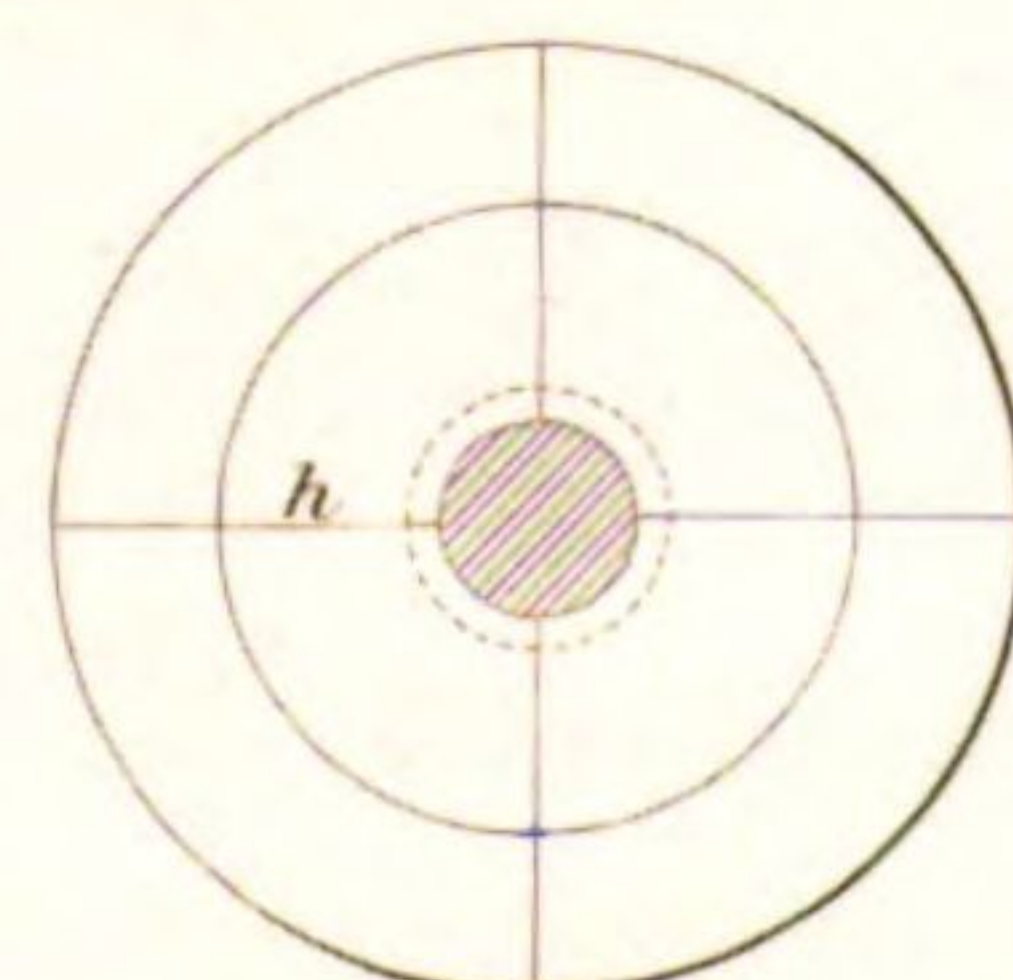


Fig. 6.



Scale $\frac{1}{8}$.



balanced, and when no appendages for holding samples are attached, is six or seven inches from the fulcrum.

Each of the several sample holders, and the torsion lever also, is separately attached; and the adjusting weight u is passed along the lever, until the position which brings the machine to an even balance is ascertained. The torsion lever requires the adjusting weight to be nearly to the small end of the first lever. Each of the ascertained positions is marked with the name of the appendage which it balances, and a small notch is cut, in the lever, to retain the adjusting weight in the proper positions. Before commencing the strain upon any sample, care should be taken to see that the adjusting weight is placed in its marked position. By employing this adjusting weight in this manner, the equilibrium of the machine is preserved in all the changes of its several sample holders, and the reading of the breaking weights is the same in all; except in torsional strains, when the 2d. lever is inoperative. The recorded breaking weight, in torsional strains, is therefore only twenty times greater than the actual weights on the platforms of the rod O ; which is equal to one-tenth, only, of the usual reading in other tests. But as the torsional lever is 25 inches long, from its axis to the point where the centre of the chain acts upon it, the weight, as above ascertained, is multiplied by 25, and the product represents the strain exerted at a point one inch from the axis of the strained bar. In practice, it is found more convenient, to read off the weights for torsion in the same manner as in other tests, and to multiply that reading by 2.5, for the strain exerted at one inch from the axis of the bar.

The rod t , with its platform and weights at the large end of the lever, is used only in testing small samples when strains of less than 5000 pounds are to be noted; which rarely occurs in testing gun metal. Ordinarily, these weights are not used, and those only which are applied on the rod O , are used.

When the rod t , (and its counterbalance weights) is not applied, the preponderance of the machine exerts a force of 5000 pounds on the sample; and the lower platform of the rod O , which resembles a weight exerting that force, is counted as such, in summing up the breaking weight.

All the working knife edges of the machine, and the seats on which they bear, are made of hardened cast steel. The knife edges of the 2d. lever, at the fulcrum, and at the point which acts directly upon the bar under

strain, are five inches long, and make an angle of 90° at their bearing edges. The angles of the other knife edges are made more acute.

PLATE XIII, figures 1 and 2, exhibits the form of the pincers which hold the sample, in tensile strains. The upper part *a* is attached to the straining stirrup *X* of the second lever, and the lower part *b* is attached to the bed-frame; *c* is the sample, in position for straining, clasped at both ends by the pincers. Figures 3 and 4, show the form of the holder used in the tensile strain of long bars of wrought iron. The holder is attached to the stirrup *X*, and receives the upper end of the bar *f*, which passes down through the bed-frame; it is held at both ends by keys. In preparing the bar for testing, the ends are first heated, and then *staved up*, until the bar is sufficiently enlarged to permit the key holes in the ends, without reducing the strength in that part, below the strength of the bar in other parts.

Figures 5 and 6, show the utensils employed in bursting hollow cylinders; *k* is a stirrup attached by the bolt *z* to the straining stirrup, and by the bolt *l*, to the conic frustrum *i*. *Q* is a part of the bed-frame; against the under side of which the shield *h* is pressed, when the cylinder is under strain. *g, g* are sections of the cylinder, resting on the shield, which fills the interior of the cylinder and supports it below. The conic frustrum *i* passes through the centre of the shield, which is cut into four equal parts. The frustrum, as it ascends, spreads the four quarters of the shield apart, and applies the bursting force against the interior surface of the cylinder.

PLATE XIV, figure 1, shows the instrument used in holding samples when under compression. *G* is a piston of hardened cast steel, which moves through a brass guide. *H* is the sample, and *I* is a steel pedestal, between which and the piston, the sample is compressed. Figure 5 is a horizontal section through the guide and the sample at *a-b*.

Figure 2 shows the form of the instruments employed in bursting small cylinders. *K* is a section of the cylinder, and *L* is a section of the shield.

Figure 3 gives the form of the indenting instruments. *M* is the piston, with the indenting chisel at its lower end. *N* is the sample to be indented. Figure 4 is a horizontal section at *c*. The indenting chisel is shown of full size, in PLATE XVI, figures 1, 2, 3, and 4.

Figures 6 and 7, PLATE XIV, show the form of the stirrup, used in holding the instruments for crushing, bursting, and indenting samples, when the straining force is applied. *A* is a stirrup of steel, attached at its upper

THE HISTORY OF THE UNITED STATES OF AMERICA

The history of the United States of America is a story of growth and development. It begins with the first settlers who came to the continent in search of a new home. These settlers, known as the Pilgrims, established the first permanent English colony in 1620. Over the years, more and more people came to the United States, and the country grew in size and population. The American Revolution was a turning point in the country's history. It was a struggle for independence from Great Britain, and it resulted in the United States becoming a sovereign nation. The Constitution was written in 1787, and it has since served as the foundation of the country's government. The United States has since played a major role in world affairs, and it has been a leader in the development of modern technology and industry. The history of the United States is a story of progress and achievement, and it is a story that continues to inspire people around the world.

Fig. 1.

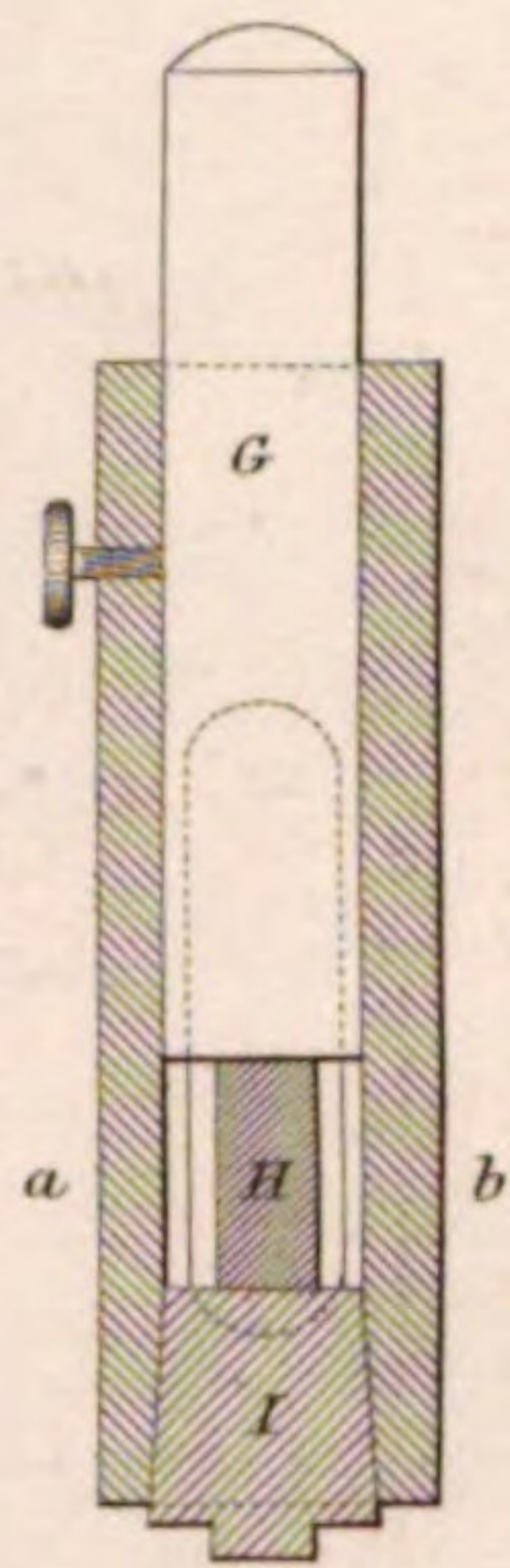


Fig. 5.



Fig. 2.

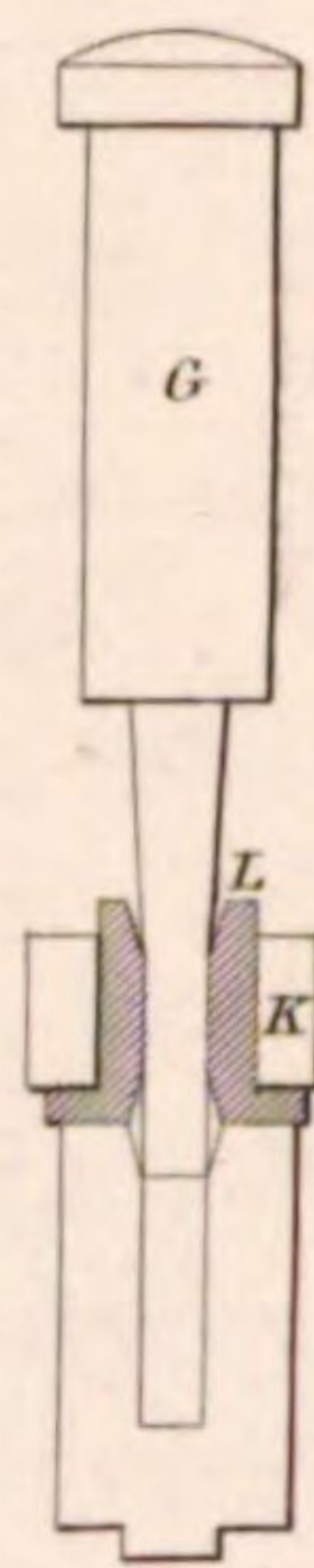


Fig. 3.

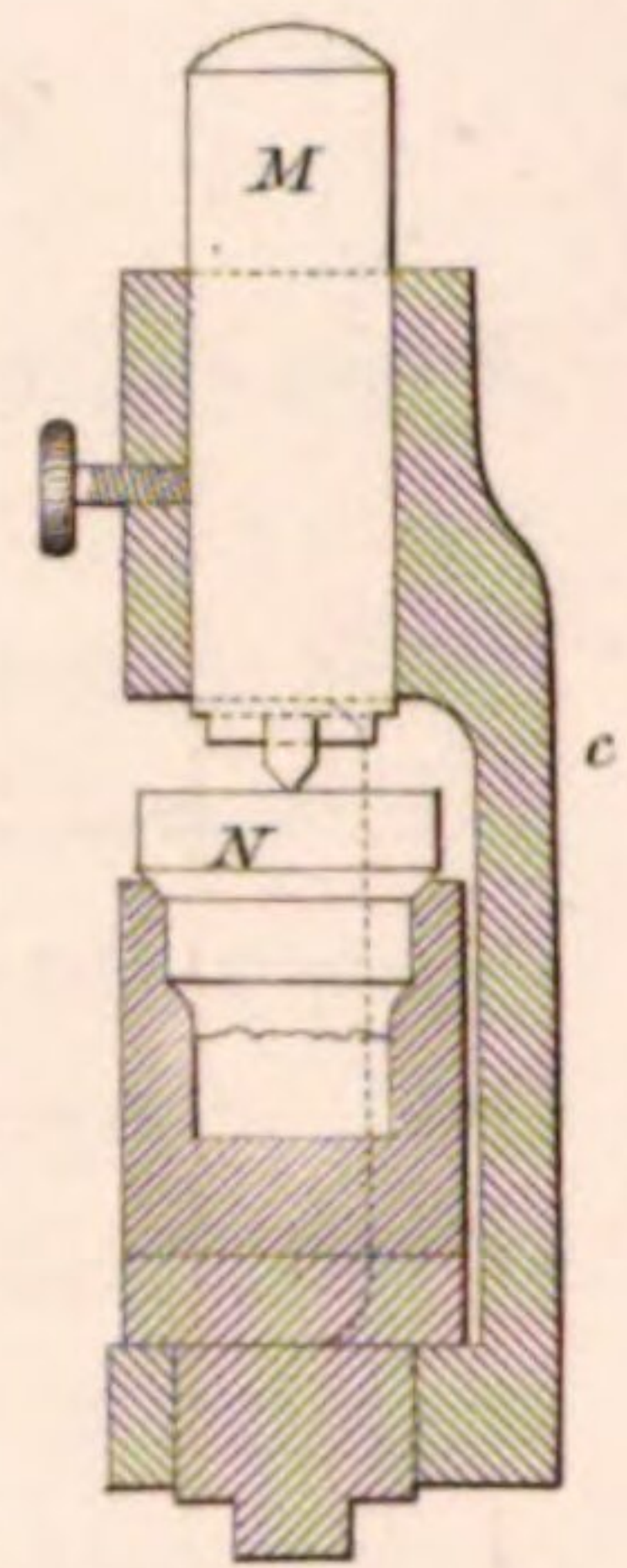


Fig. 4.



Scale $\frac{1}{4}$.

Fig. 6.

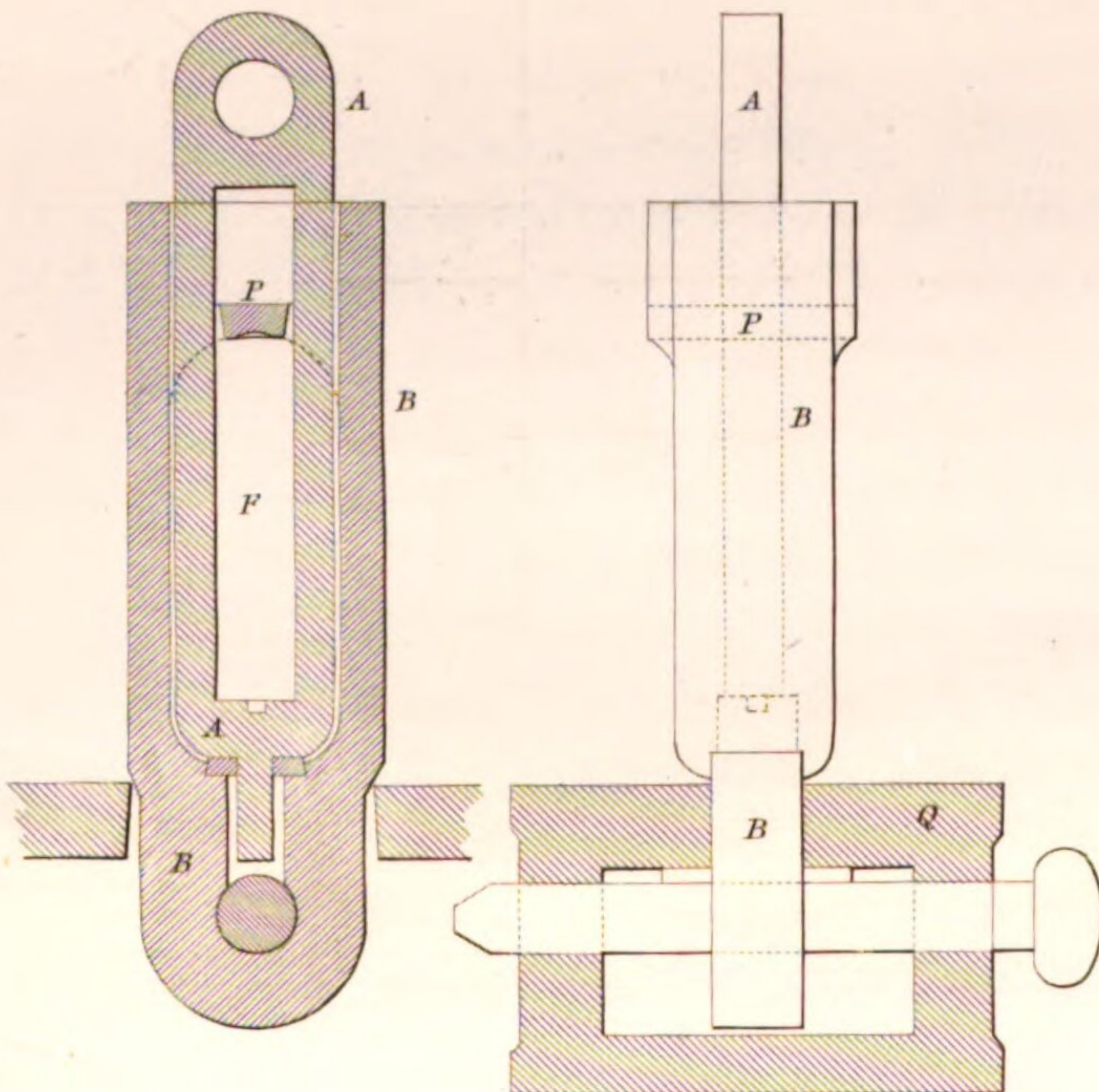


Fig. 7.

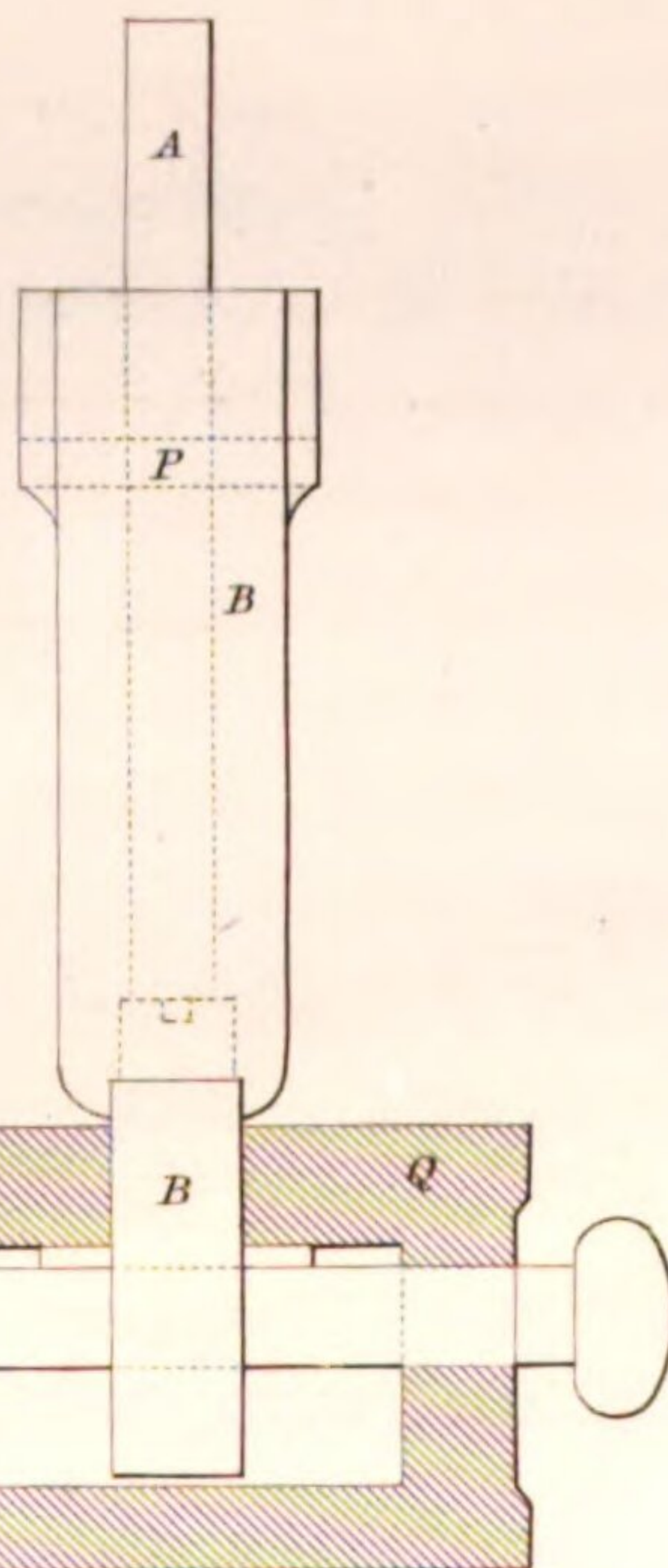


Fig. 8.

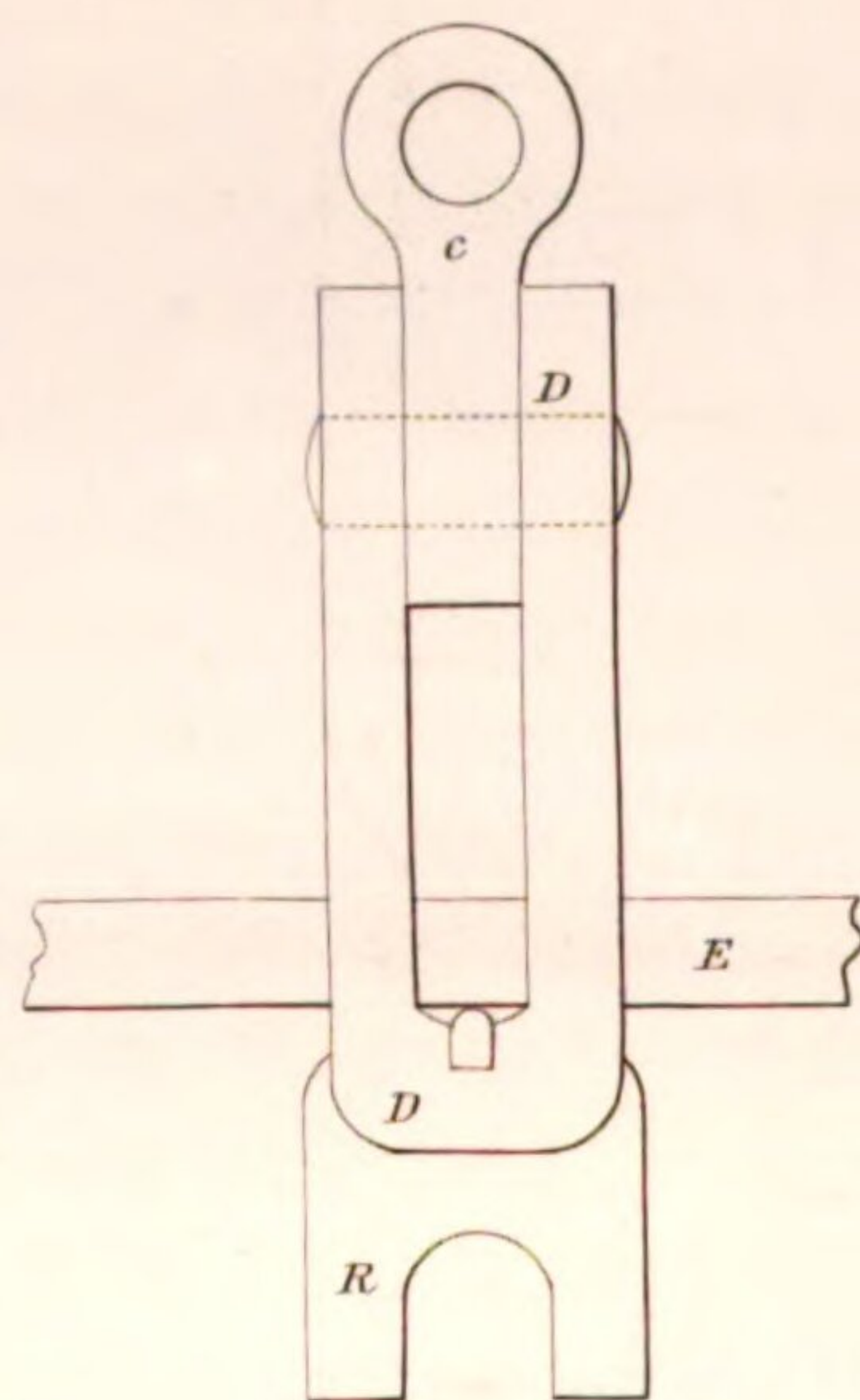
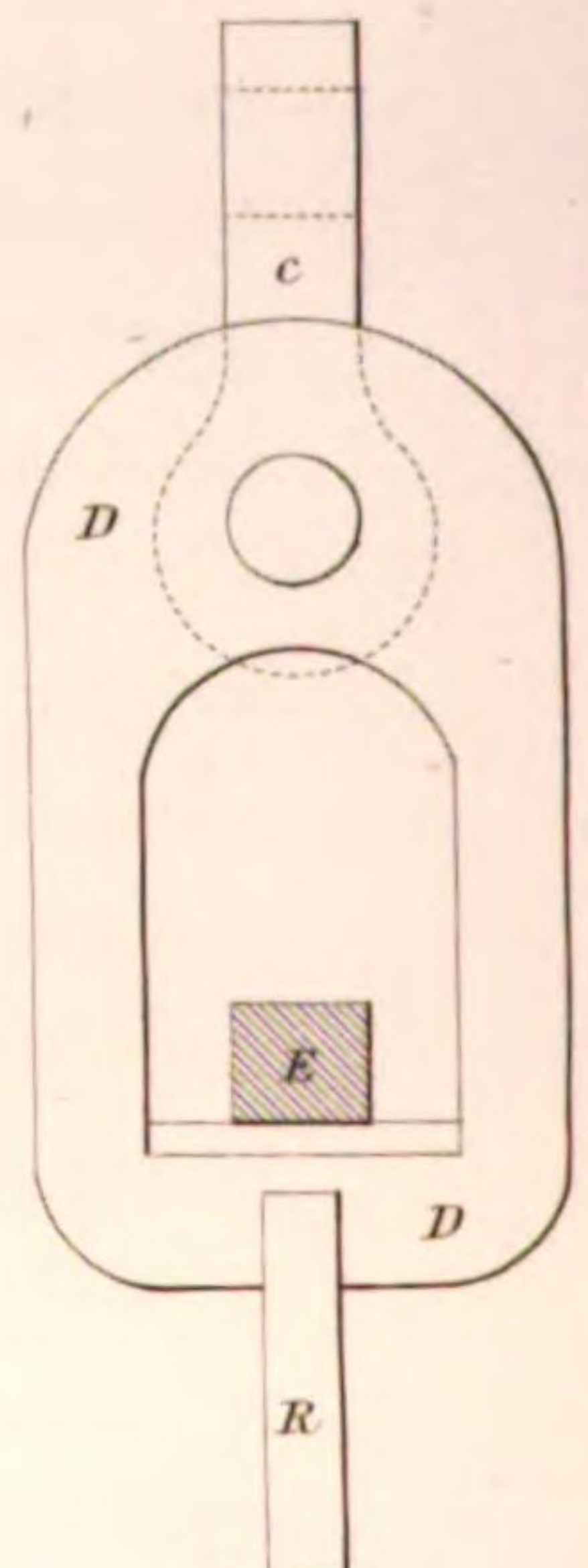


Fig. 9.



Scale $\frac{1}{8}$.

Fig. 1.

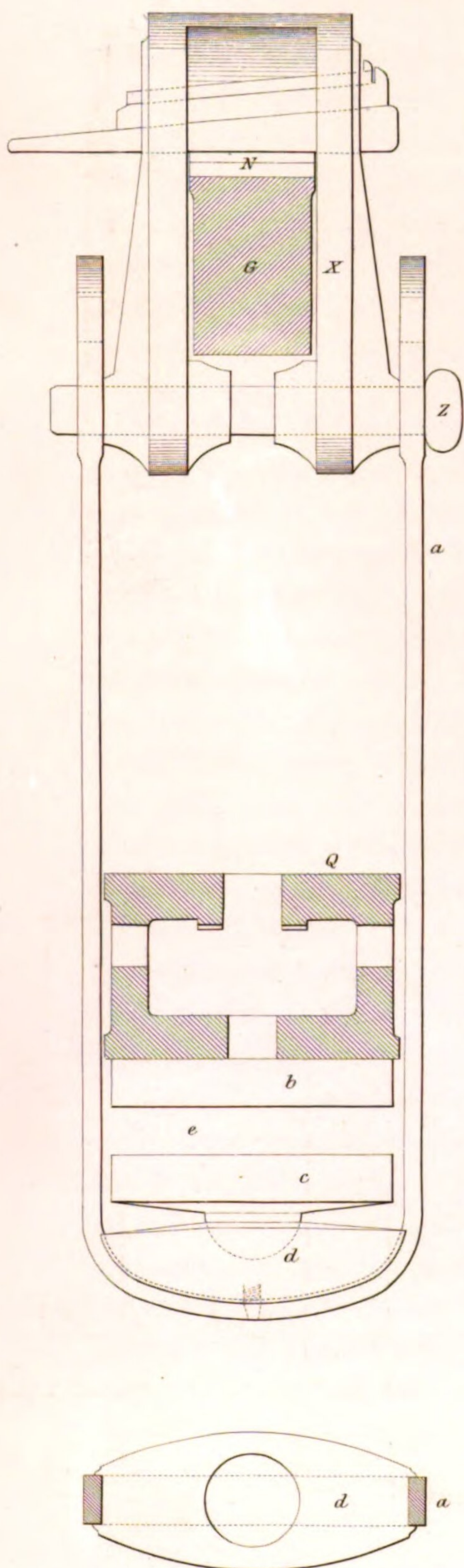
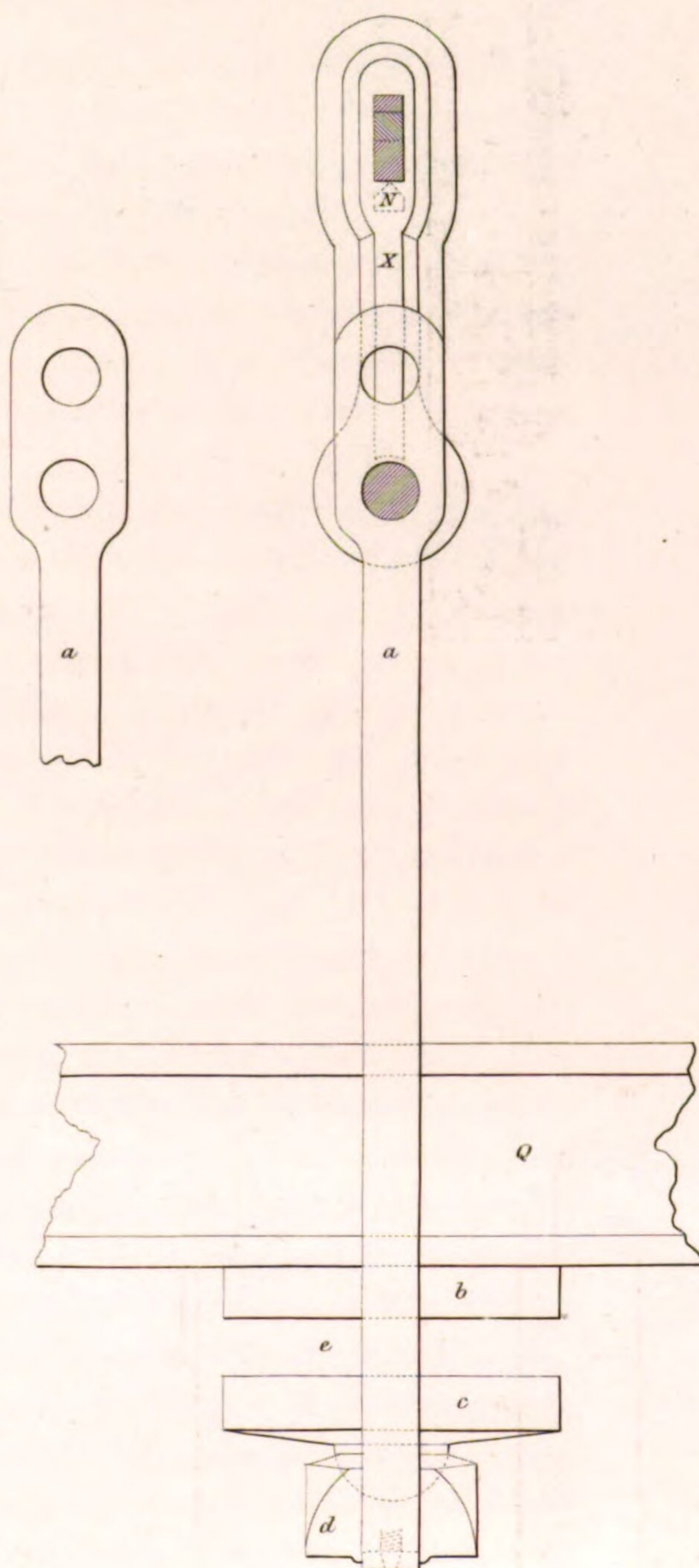


Fig. 2.



Scale $\frac{1}{8}$.

end, to the straining stirrup *X*; and the part *B*, which is made of cast iron, is attached to the bed-frame *Q*. The instruments which hold the samples are inserted in the space *F*. The heads of the pistons, rest against the bar *P* (which is a part of the stirrup *B*), when the strain is applied.

Figures 8 and 9, show the form of the stirrup employed in transverse strains. *C* is a link of cast steel, which is attached to the straining stirrup *X*. *R* is a guide, at the lower end of the stirrup *D*, which passes through a mortice in the bed-piece. *E* is a part of a bar, in position for testing transversely.

PLATE XV, figures 1 and 2, shows the apparatus employed in crushing stone, brick, marble, or wood. *G* gives a section of the second lever of the testing machine, and *X* shows the form of the straining stirrup, with its adjusting keys resting on the knife edge *N*, and *Z*, the bolt, to which the upper ends of all sample holders are attached. *Q* is a part of the bed-frame. *a* is a stirrup of wrought iron, which envelops the bed-frame, and is attached to the straining stirrup, by the bolt *Z*. *d* is a piece of cast iron, resting in the fold of the stirrup at the bottom, the upper surface of which contains a hemispherical cavity. It is held in its place by a guide pin and a groove, on the under side. *c* is a plate, on which the body to be crushed is placed. The hemispherical projection, on its under side, is made to fit the cavity in the transom below, and to form an universal, or a ball and socket, joint. This permits the upper surface of the plate to incline in any direction which inequalities of thickness in a body placed on it may require. *e* is the space to be occupied by the body under compression. This space may be varied, so as to accommodate a body of any height between 2 and 10 inches, by changing the position of the keys and of the bolt holes in the stirrups, and by removing or inserting the loose plate *b* on the under side of the bed-frame.

PLATE XVI, figures 1, 2, 3, and 4, gives the form of the indenting tool, at full size. Figure 5 shows, at full size, the form of a bar of bronze, or of wrought iron, prepared for tensile strain. The perpendicular projections at *V*, *V*, are designed for determining the elongation of the bar, between these points, while under strain. It is measured by a graduated metallic scale, which is sloping on the edges. The narrow end is inserted between the projections before the strain is commenced, and afterwards, at stated additions of strain, until rupture occurs.

Figure 6 gives the form of a bar of cast iron, prepared for testing its ten-

sile strength. Figures 7 and 8, give the form of a bar, as it is cast, for testing by torsion and by compression. The parts *A*, *A* are made square; against which, the holding keys are pressed. All other parts are round. The part between the keys is dressed to a true cylinder, the length of which should not be less than three diameters. This length is necessary, to allow a full development of the fracture to occur within the dressed part of the bar. The part *B* is used for compression. It is separated from the other part, and accurately turned to a cylinder of uniform diameter, with its ends in planes perpendicular to its axis. The length of the cylinder should be between two and three diameters. If longer, the bar may suffer deflection, before fracture occurs, and thus bring an indirect transverse strain to bear upon it. If it be shorter, the form of breaking may be that of pulverizing, instead of giving the natural and regular form of fracture, due to the material crushed. Figure 9 is the form of a bar cast for transverse and tensile tests. The part *C* is cylindrical, and is used in the tensile test. The other part is square, and used in transverse tests. The cylinder is reduced to the form, figure 6, to fit the pincers used in tensile strains. Its diameter in the smallest part of the middle, is accurately measured before it is placed in the pincers for testing. The square part, used in transverse tests, is dressed smooth by the file or by the grindstone, in the places which bear on the supports, at the ends; and in the middle, on the four sides, where the breadth and depth are measured. These measures may be taken more accurately after the bar is broken; and they should be taken in three places, for both breadth and depth, and the mean of each be used in computing the strength.

PLATE XVII, gives a full size drawing of the sliding calipers, used in measuring the samples of metal tested. Its sliding scale is divided into twentieths of an inch. A vernier is attached containing fifty divisions, which cover forty-nine divisions on the sliding scale, and it reads thousandths of an inch. It will measure any space not exceeding two and a half inches, giving the result to the nearest one thousandth part of an inch. The accuracy of its adjustment may be readily verified, by pressing the points together gently, and noting whether the zero marks coincide. If from the wearing of the steel points, or from other cause, the adjustment should become incorrect, it may be readjusted by turning the screw which forms one of the points.

Indenting Tool.

Fig. 1.

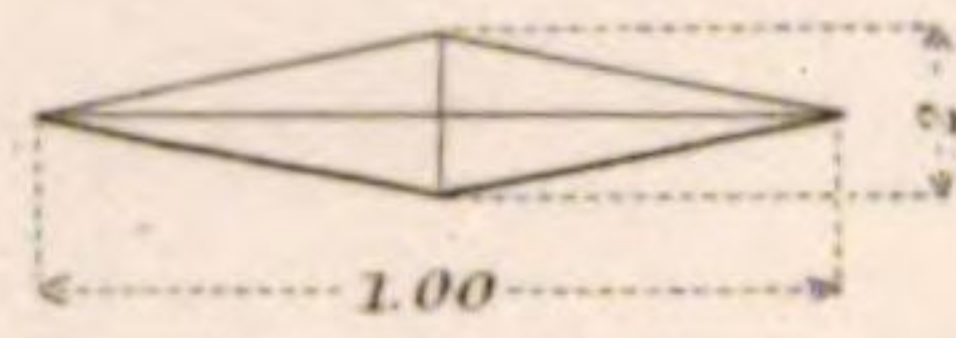
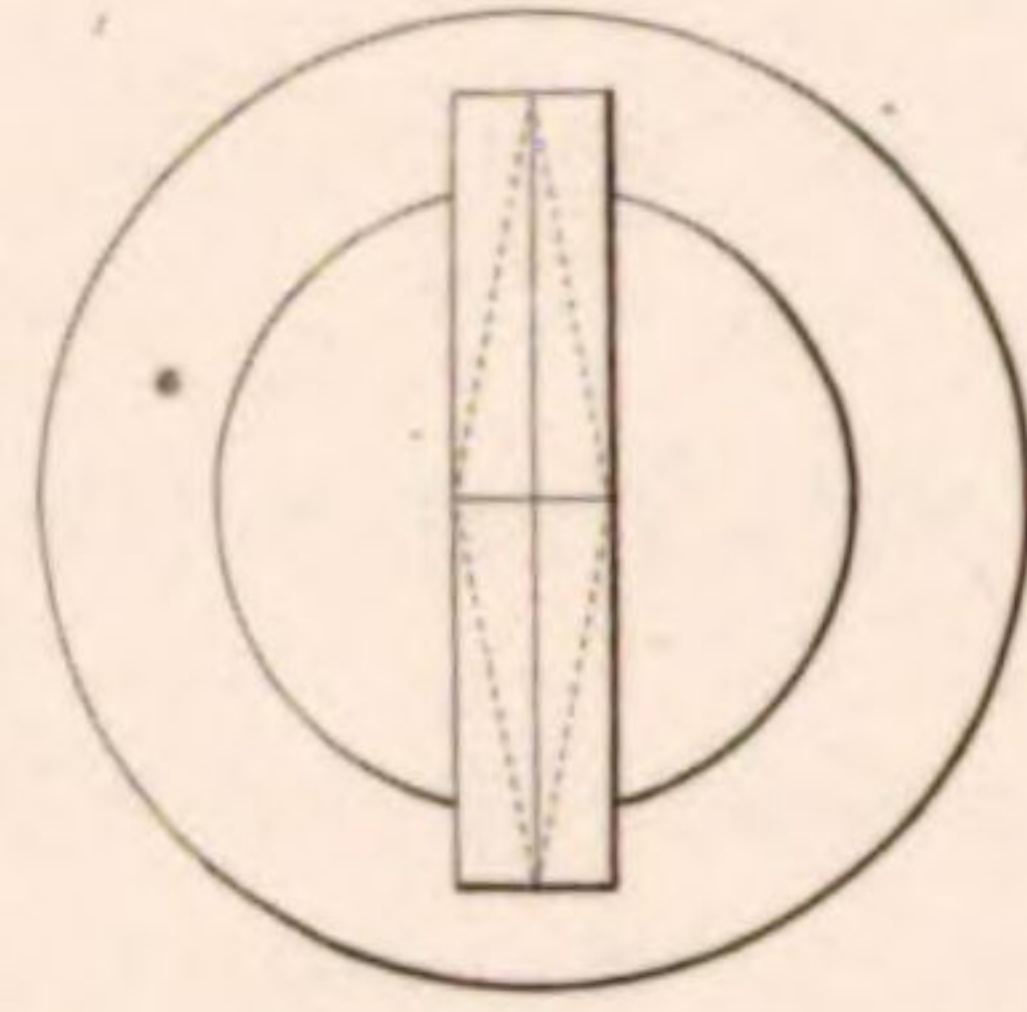


Fig. 2.



Full Size.

Fig. 3.

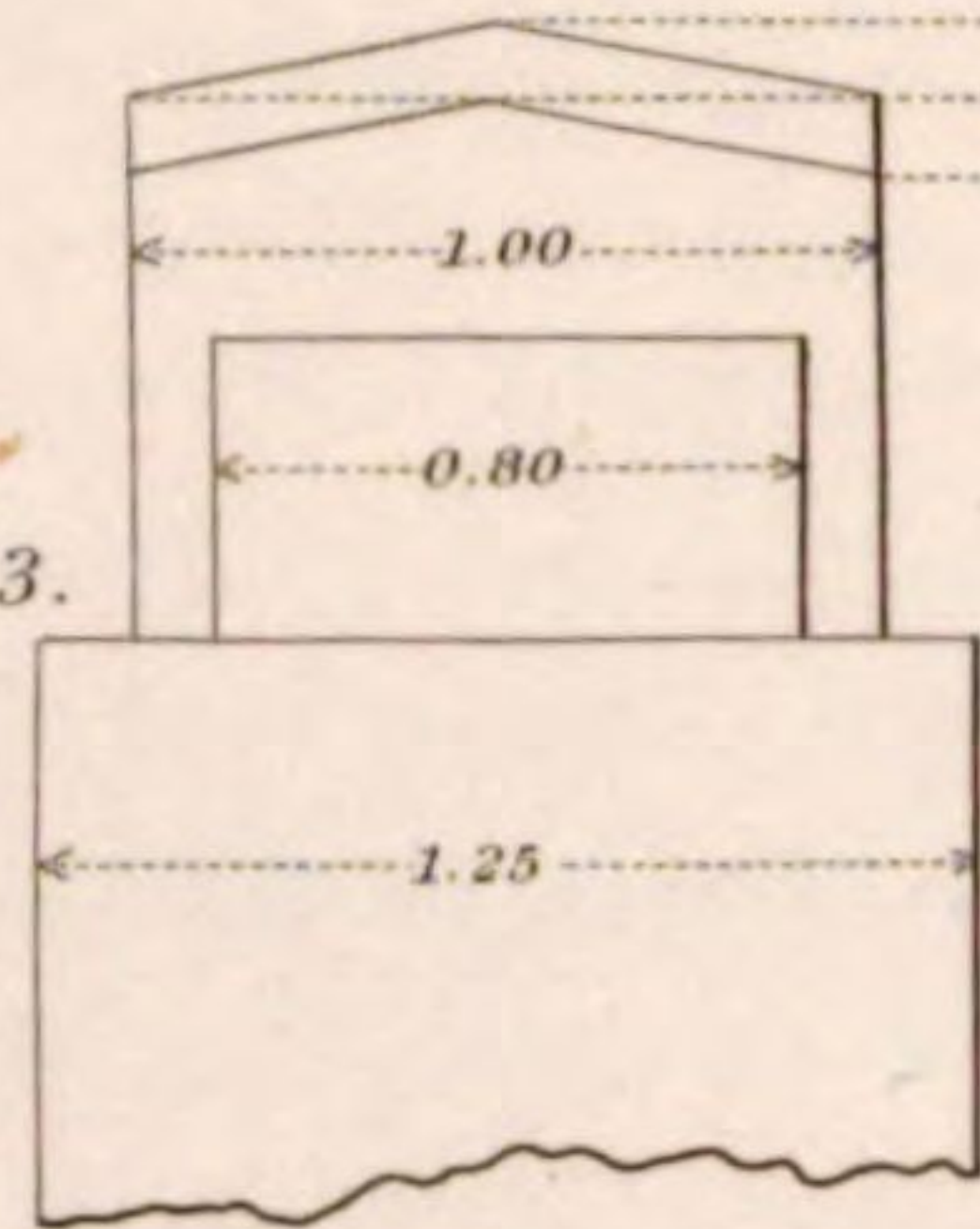


Fig. 4.

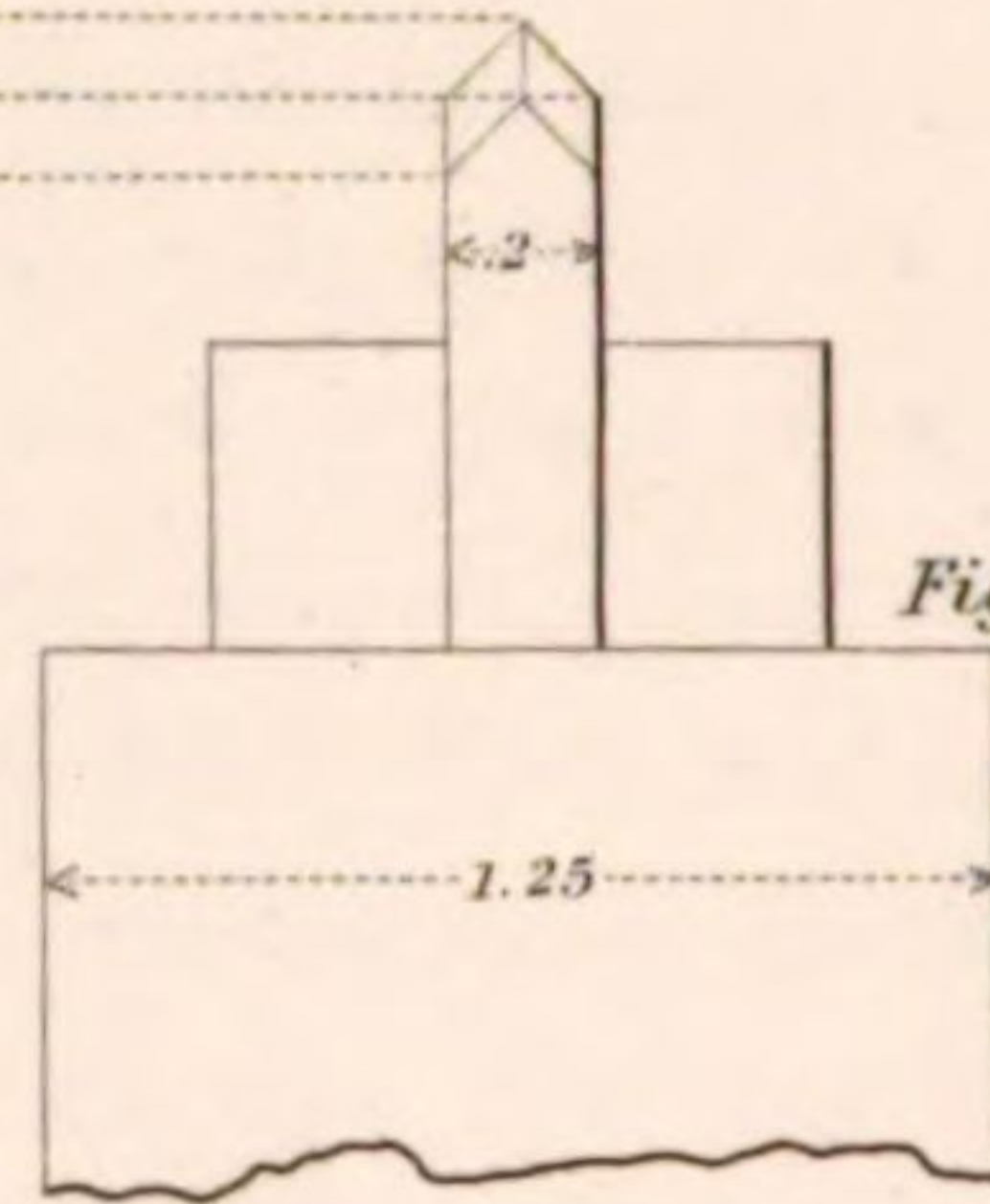


Fig. 6.
Full Size.

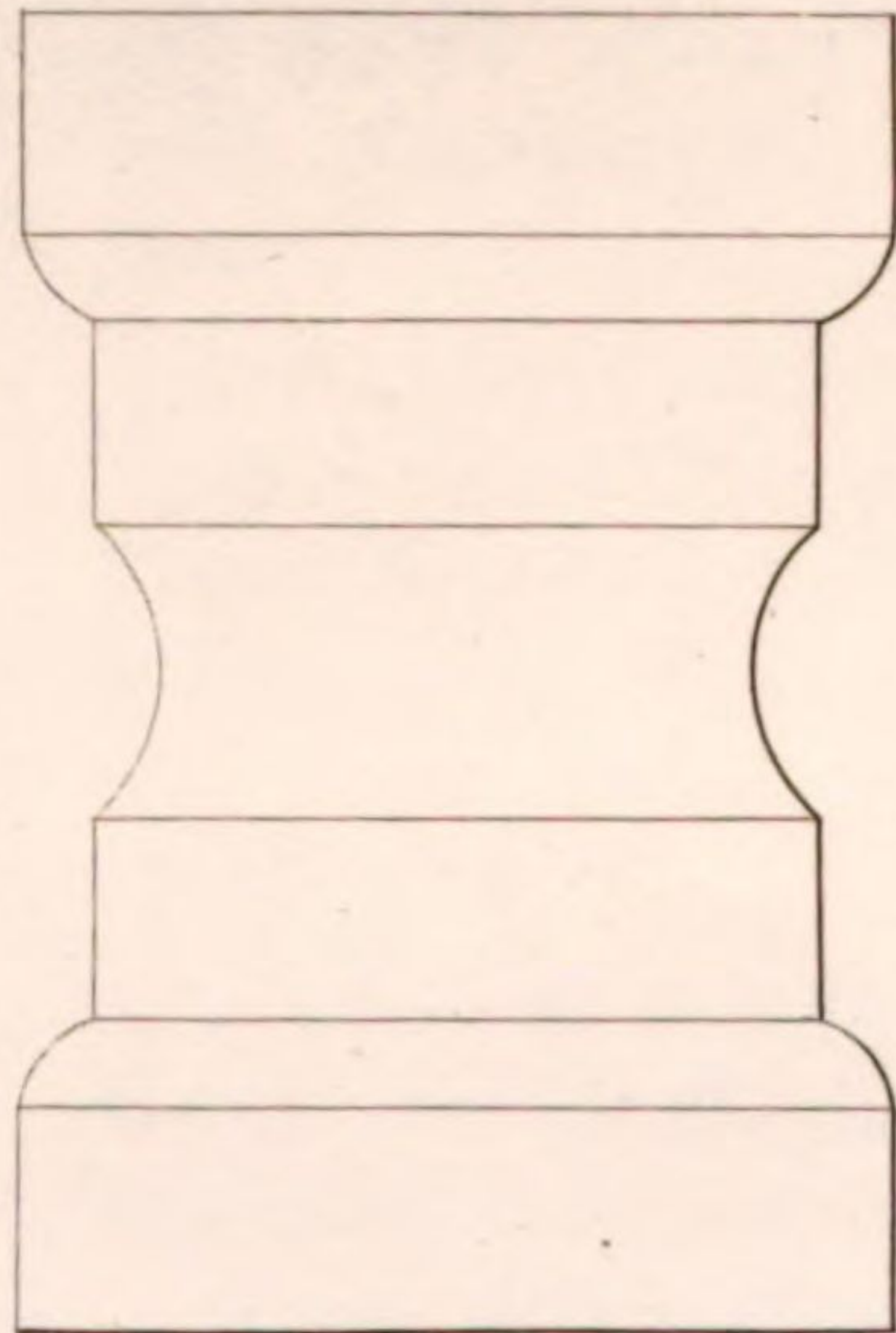


Fig. 5.
Full Size.

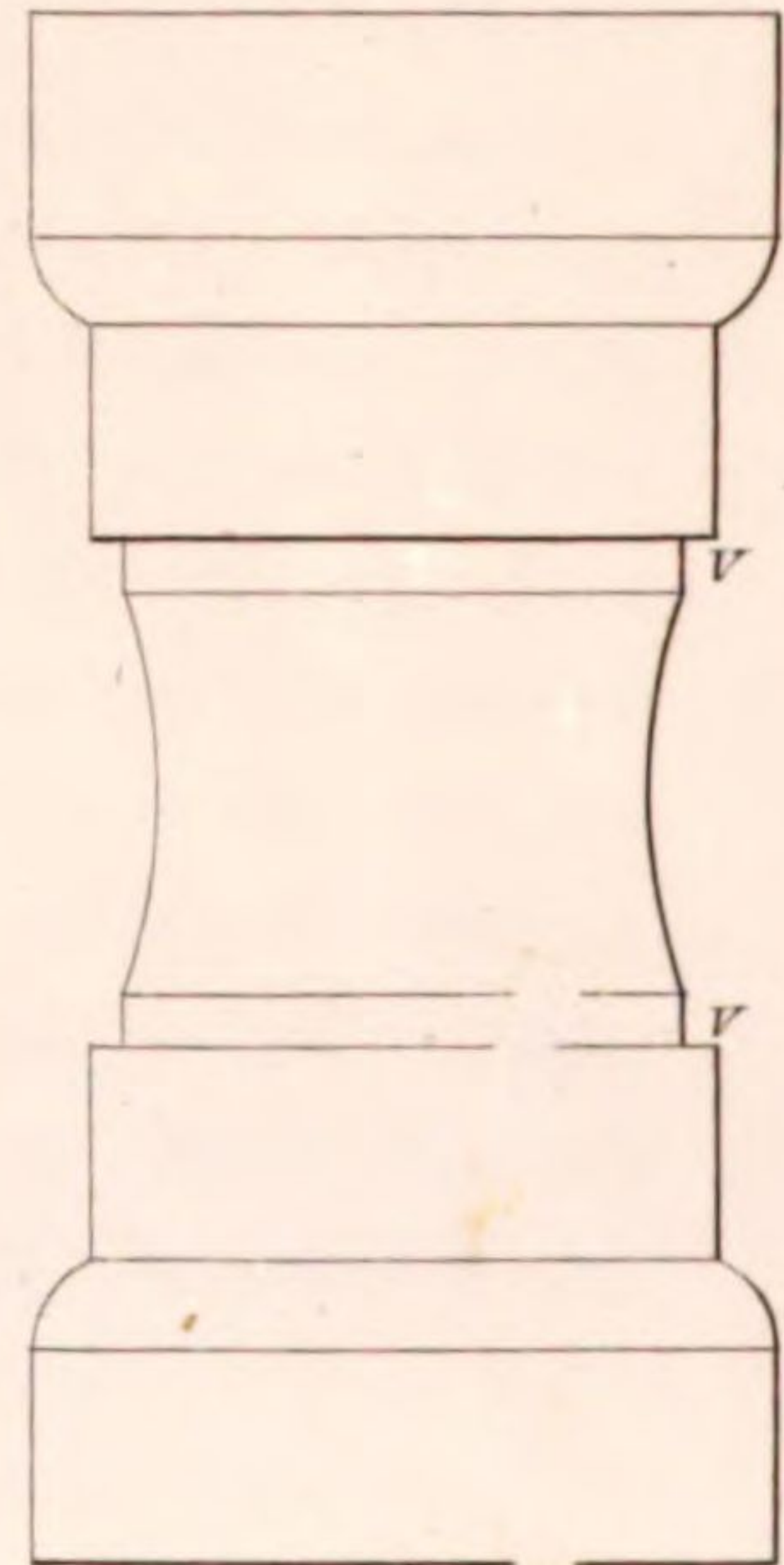


Fig. 8.

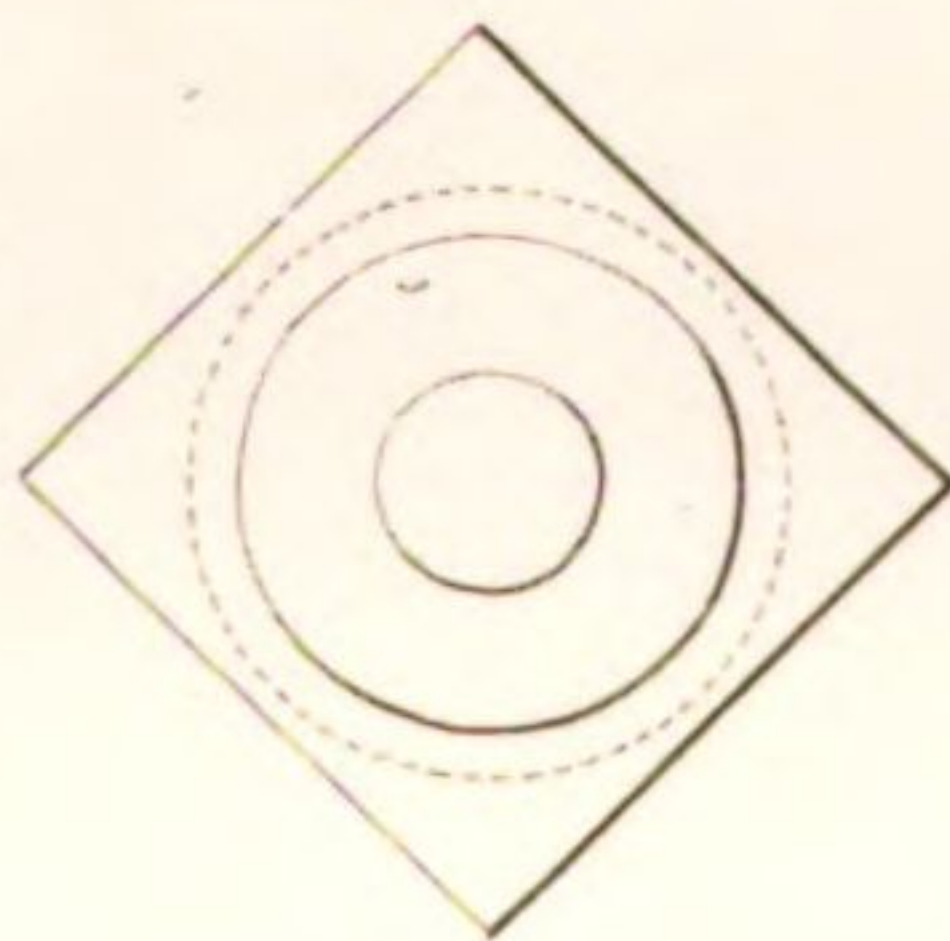
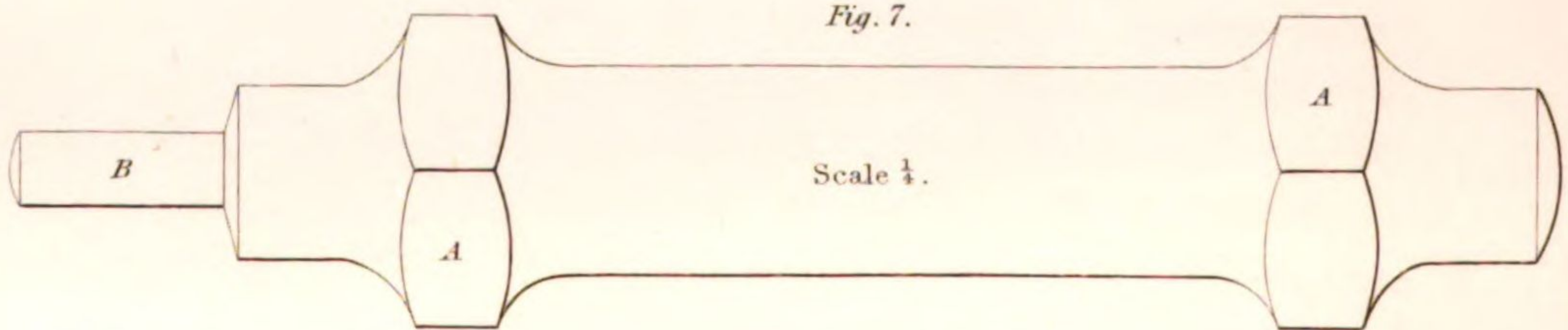
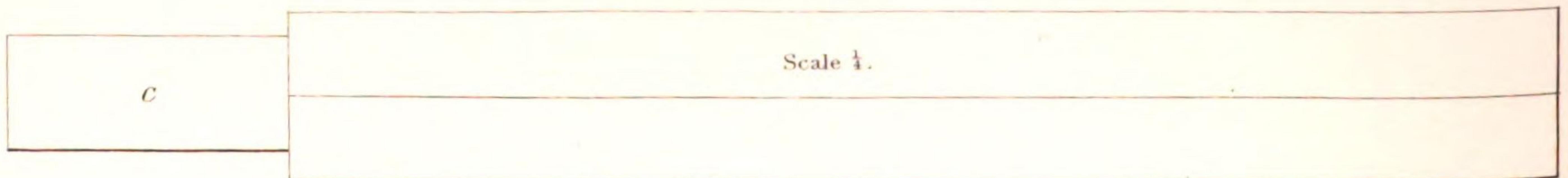


Fig. 7.



Scale $\frac{1}{4}$.

Fig. 9.



Scale $\frac{1}{4}$.

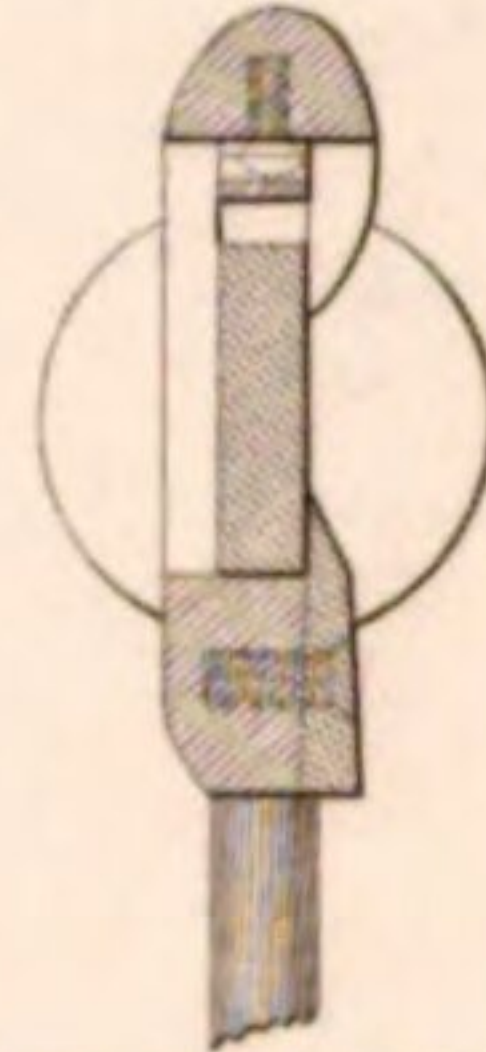
Specimen Callipers.

Full Size.

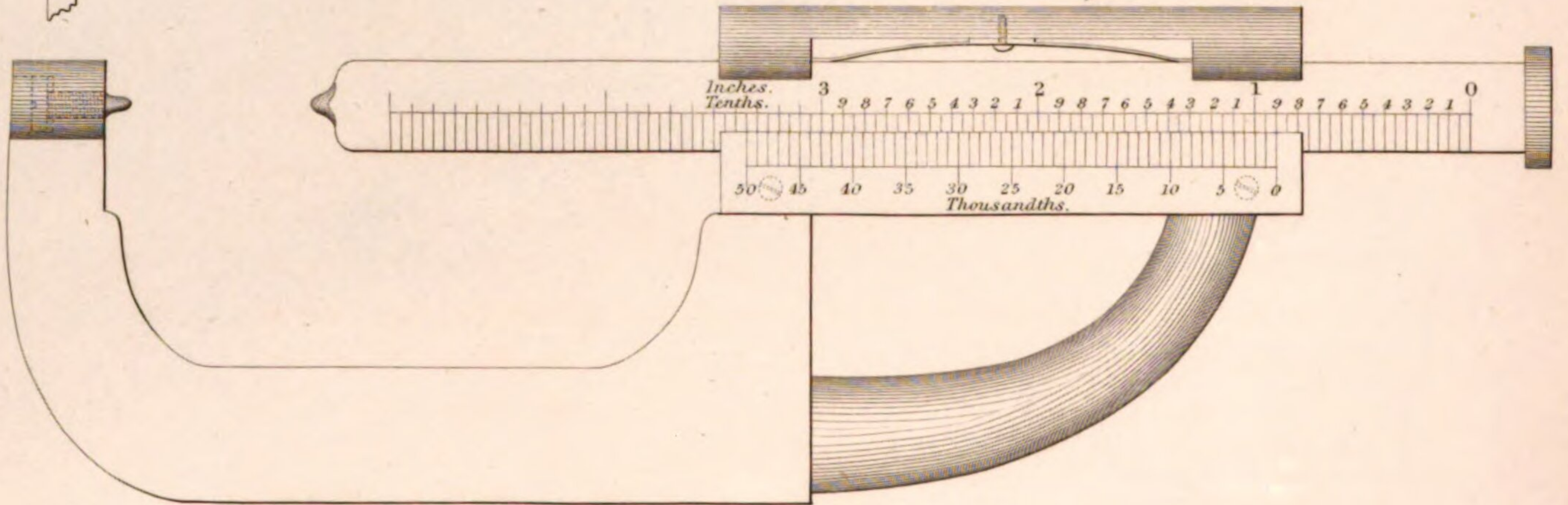
End View.



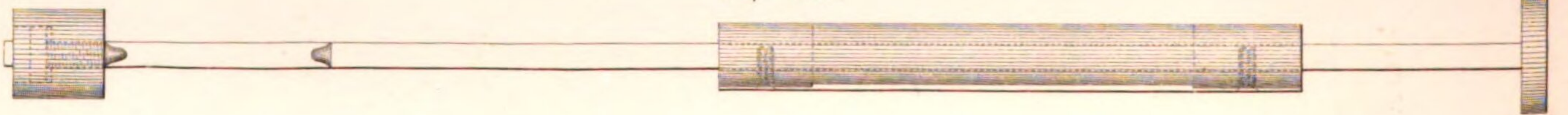
Section.



Elevation.



Top View.



When placing any bar in the machine for testing, the operator should estimate to what extent the bar may yield to deflection, elongation, or compression, (as the case may be) in order that the position of the second lever may be so adjusted, in the beginning of the strain, that it will be in the upper half of its range of motion when the bar breaks. The position of the lever may be varied, after the bar is placed in the machine, by means of the keys at *N*, which pass through the upper part of the stirrup *X*.

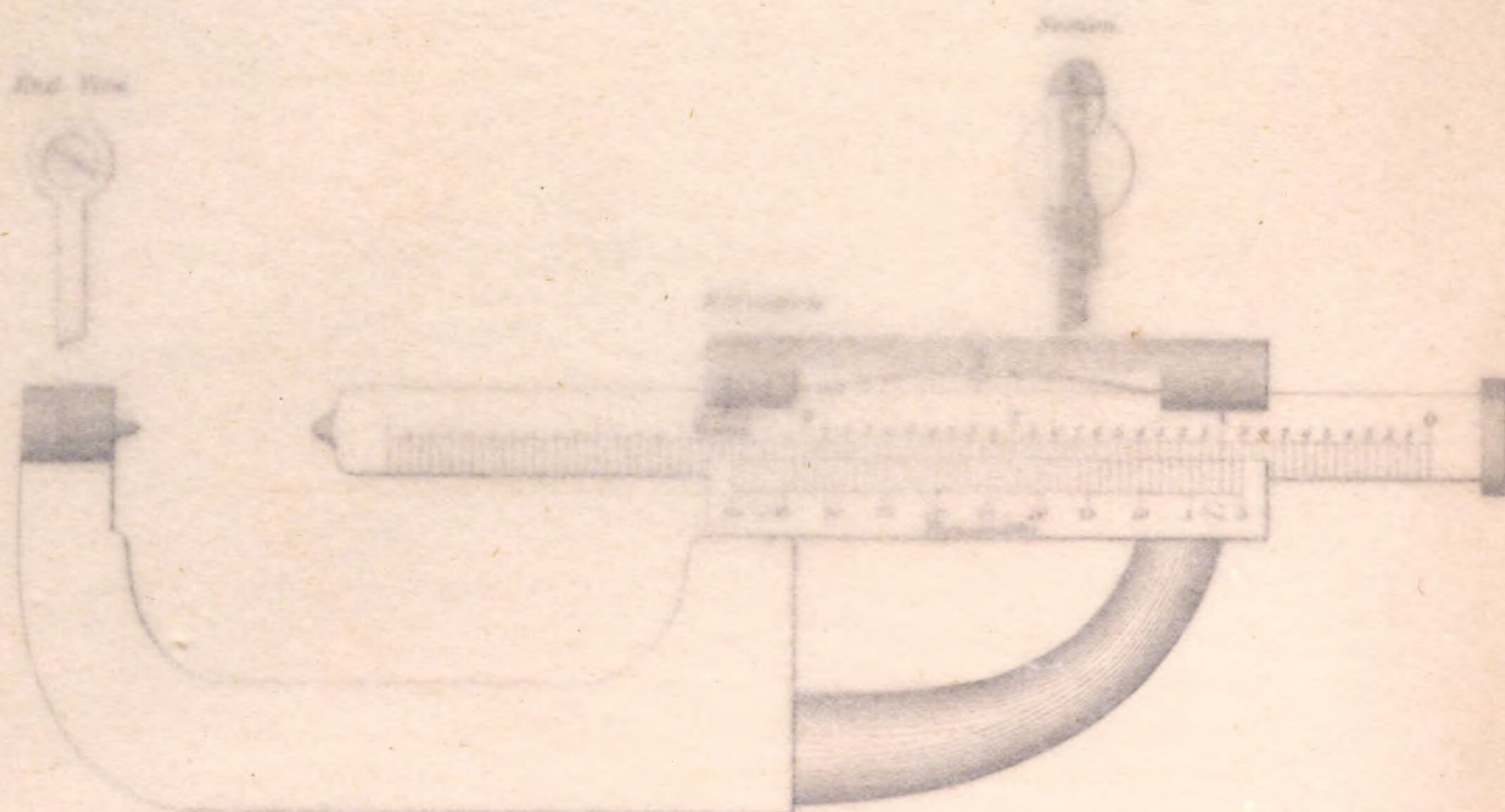
HYDROMETER.

PLATE XVIII, exhibits the form of the instrument used in determining the specific gravity of metals, and PLATE XIX, represents a full size vertical section of the same, with the details of construction. It is constructed on the principle of Nicholson's hydrometer; the bulb is 7.5 inches diameter and 8 inches high, made of copper, in one piece, without seam. The copper is .03 thick, and is deposited on a mould, of low fusible metal, by the Electro-galvanic process. A handle of brass wire, with broad flanges at the ends, is inserted in the upper part of the mould, and a cone of brass is inserted in the bottom of the mould, before the copper is deposited; the copper covering and uniting with both. The brass cone is bored through its axis, and screw threads are cut in it. After the bulb is formed, the fusible mould is melted, and withdrawn through the aperture in the brass cone. The aperture is then closed by a small screw, and made air tight by close fitting, and by sealing wax spread over it. A solid stem of brass is then screwed into the bottom of the bulb. A vertical index stem made of steel, is inserted in the upper part of the handle. The upper end of the stem receives the weight pan, which is supported in its place by a conical socket on its under side. The height of the hydrometer, from the bottom of the ball to the weight pan, is 21 inches. All of the exterior surface is protected by Electro-gilding.

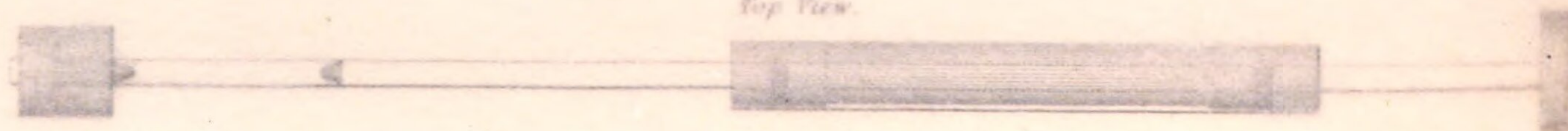
The weight of the bulb, including the handle and brass cone, is about 15,850 grains; the lower stem and ball weigh about 20,320 grains, and the weight pan 660 grains: making the total weight of the hydrometer about

Specimen Callipers.

Full Size



Top View.



When placing any bar in the machine for testing, the operator should estimate to what extent the bar may yield to deflection, elongation, or compression, (as the case may be) in order that the position of the second lever may be so adjusted, in the beginning of the strain, that it will be in the upper half of its range of motion when the bar breaks. The position of the lever may be varied, after the bar is placed in the machine, by means of the keys at *N*, which pass through the upper part of the stirrup *X*.

HYDROMETER.

PLATE XVIII, exhibits the form of the instrument used in determining the specific gravity of metals, and PLATE XIX, represents a full size vertical section of the same, with the details of construction. It is constructed on the principle of Nicholson's hydrometer; the bulb is 7.5 inches diameter and 8 inches high, made of copper, in one piece, without seam. The copper is .03 thick, and is deposited on a mould, of low fusible metal, by the Electro-galvanic process. A handle of brass wire, with broad flanges at the ends, is inserted in the upper part of the mould, and a cone of brass is inserted in the bottom of the mould, before the copper is deposited; the copper covering and uniting with both. The brass cone is bored through its axis, and screw threads are cut in it. After the bulb is formed, the fusible mould is melted, and withdrawn through the aperture in the brass cone. The aperture is then closed by a small screw, and made air tight by close fitting, and by sealing wax spread over it. A solid stem of brass is then screwed into the bottom of the bulb. A vertical index stem made of steel, is inserted in the upper part of the handle. The upper end of the stem receives the weight pan, which is supported in its place by a conical socket on its under side. The height of the hydrometer, from the bottom of the ball to the weight pan, is 21 inches. All of the exterior surface is protected by Electro-gilding.

The weight of the bulb, including the handle and brass cone, is about 15,850 grains; the lower stem and ball weigh about 20,320 grains, and the weight pan 660 grains: making the total weight of the hydrometer about

36,830 grains. Its general form, and the distribution of the metal within it, place the centres of gravity and buoyancy so far apart, that it readily takes a vertical position when immersed, and will deviate very little from it, however irregularly it may be loaded.

The maximum buoyancy of the hydrometer is 14,600 grains, and, when loaded to zero, it displaces 51,430 grains of water. The buoyancy may be reduced one-half, by increments of 500 grains each, by placing one or more of the adjusting weights over the ball, at the bottom of the stem. Such a reduction of the buoyancy is found convenient in practice, when weighing small samples, as it prevents the necessity for placing and displacing numerous weights on the pan.

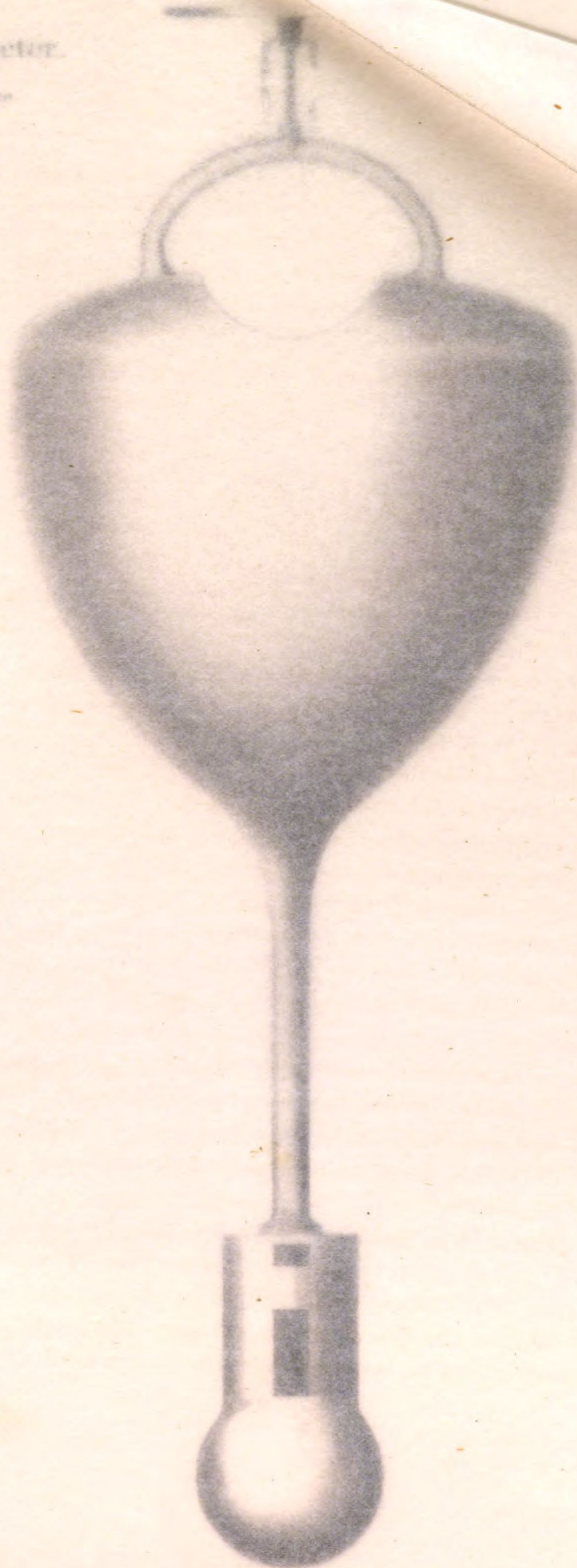
The index stem is .071 inch diameter; a length of one inch displaces one grain of water. Four points of silver wire, made thin and sloping at the ends, are attached near the stem, and are so arranged as to form a scale of weights, in tenths of a grain. The two nearest opposite points are one-tenth of an inch apart. When the instrument rests with one of these points above, and the other beneath the surface of the water, it is at its zero. When either of them touches or is even with the surface, the load is one-tenth of a grain too heavy, or too light, and if either passes through the surface, the error is then two-tenths of a grain. If either of the two points which are more distant from the zero, touches the surface of the water, the load is then deficient, or in excess, three-tenths of a grain; and if the heel of either of these points passes the surface, the error is then four-tenths of a grain. Careful observation of the position of these points, when the hydrometer is immersed and at rest, will serve to indicate the true balance, when the zero mark may be above or below the surface of the water, within a given limit. By this method, the inconvenience and delay of bringing the zero to the surface of the water, by the decimal parts of the grain weight, is avoided.

PLATE XX gives the form, and the dimensions, of all the weights used on the pan.

The water in which the hydrometer is immersed, is contained in a cistern of glass, 25 inches deep, and not less than 12 inches diameter. If the bottom of the cistern is not level, a flat plate should be placed over it, and be supported horizontally on three legs. The height of the water in the cistern should be such, that when the bottom of the hydrometer descends

Hydrometer.

Half Size



Designed by W. Wade.

C. M'Clintock & Co.

PROPERTIES OF METALS

The hydrometer is of a certain form, and the distribution of the metal within it, is such that it floats in liquids and buoyancy so far apart, that it readily takes its position in any liquid, and will deviate very little from it, however much it may be disturbed.

The weight of the hydrometer is 14,985 grains, and, when placed in water, it displaces 14,985 grains of water. The buoyancy may be increased or diminished, by increasing or decreasing the weight, by placing one or more of the adjusting weights over the ball, or the bottom of the stem. Such a correction of the buoyancy is known as the correction in practice, when weighing small samples, as it prevents the necessity for placing and displacing numerous weights on the pan.

The index stem is .071 inch diameter; a length of one inch displaces one grain of water. Four points of silver wire, made thin and tapering at the ends, are attached near the stem, and are so arranged as to form a scale of weights, in tenths of a grain. The two nearest opposite points are one-tenth of an inch apart. When the instrument rests with one of these points above, and the other beneath the surface of the water, it is at its zero. When either of them touches or is even with the surface, the load is one-tenth of a grain too heavy, or too light, and if either passes through the surface, the error is then two-tenths of a grain. If either of the two points which are one-tenth of an inch apart, touches the surface of the water, the load is then one-tenth of a grain too heavy, or too light, and if the head of either of these points passes the surface, the error is then four-tenths of a grain. Having determined the position of these points, when the hydrometer is suspended and at rest, with water to indicate the true balance, when the zero mark may be above or below the surface of the water, within a given limit. By this method, the inconvenience and delay of bringing the zero to the surface of the water, by the addition of the grain weight, is avoided.

PLATE XX gives the form, and the dimensions of all the weights used on the pan.

The water in which the hydrometer is suspended, is contained in a cistern of glass, 25 inches deep, and not less than 15 inches diameter. If the bottom of the cistern is not level, a flat plate should be placed over it, and be supported horizontally on three legs. The height of the water in the cistern should be such, that when the bottom of the hydrometer reaches

Hydrometer.

Half Size.



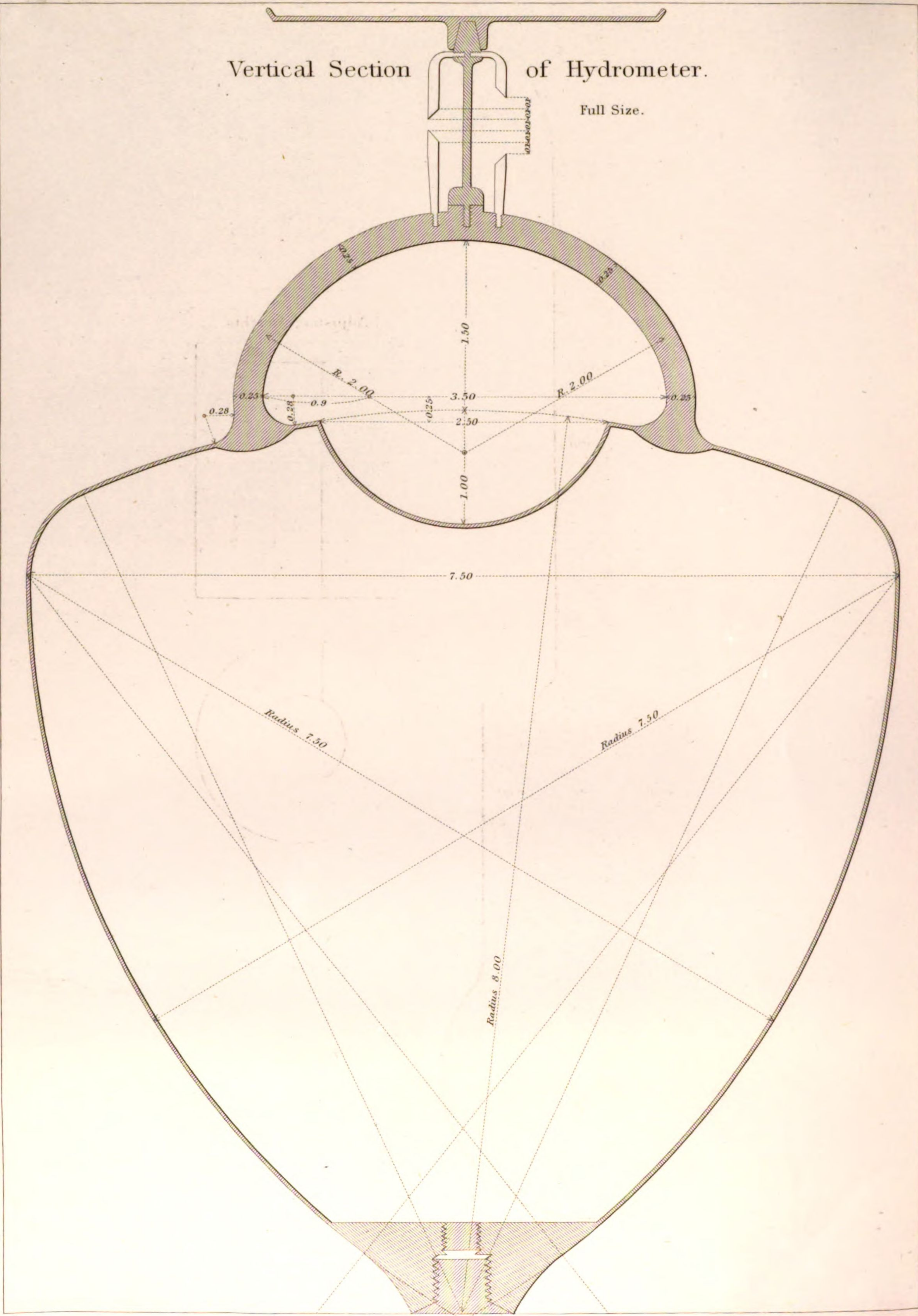
Designed by W. Wade.

D. McClelland Sc.

Vertical Section

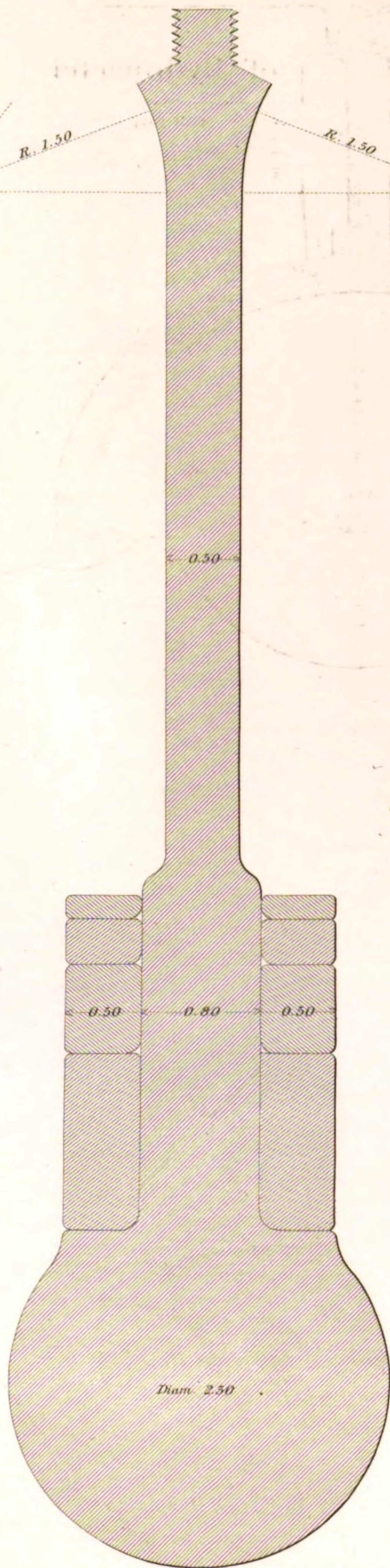
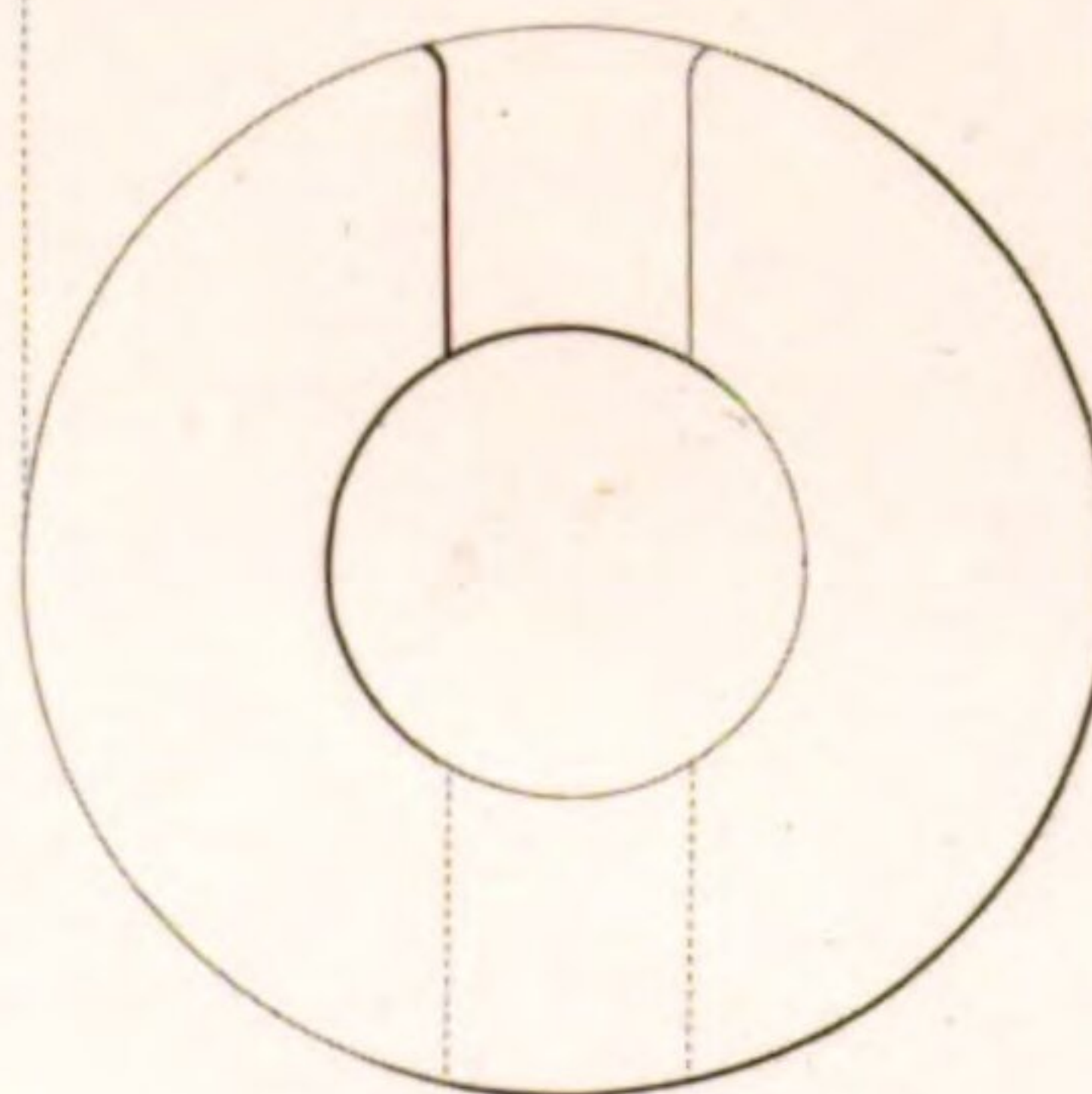
of Hydrometer.

Full Size.



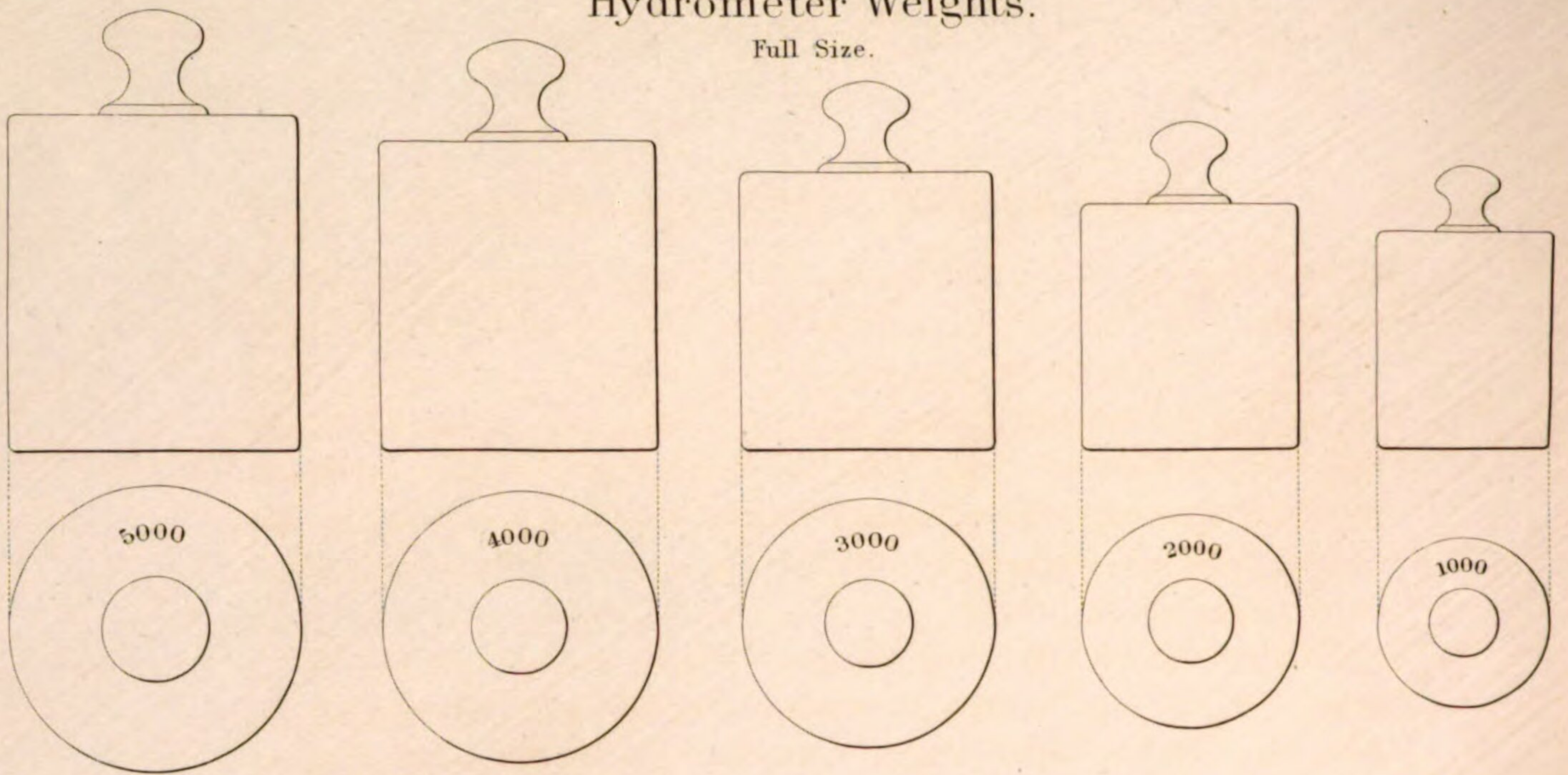


Adjusting Weights.



Hydrometer Weights.

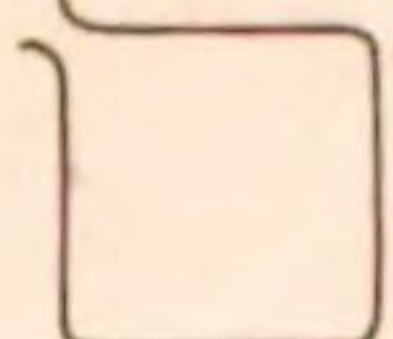
Full Size.



0.5 Grain.



0.4 Grain.



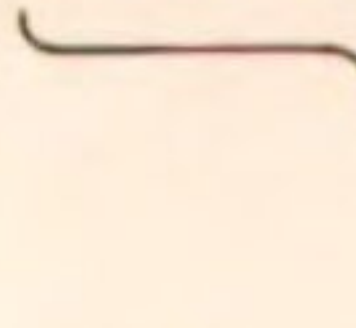
0.3 Grain.



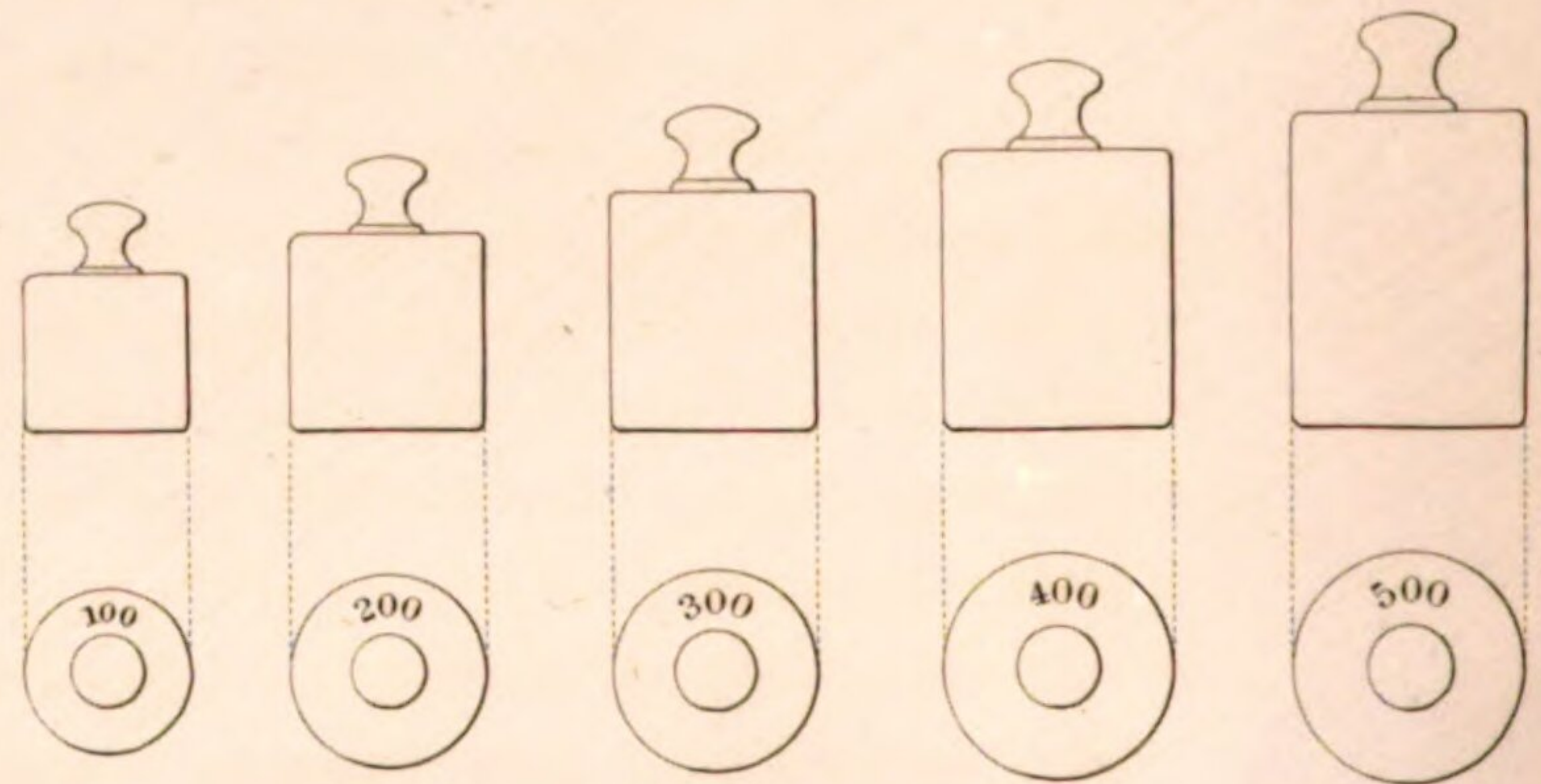
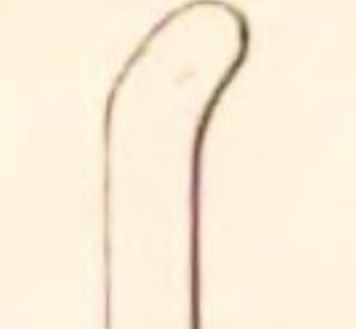
0.2 Grain.



0.1 Grain.



10 Grains.



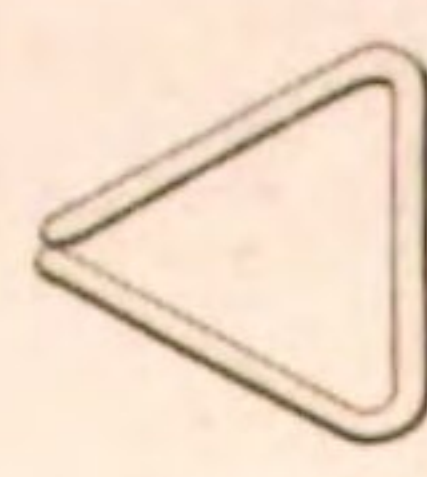
1 Grain.



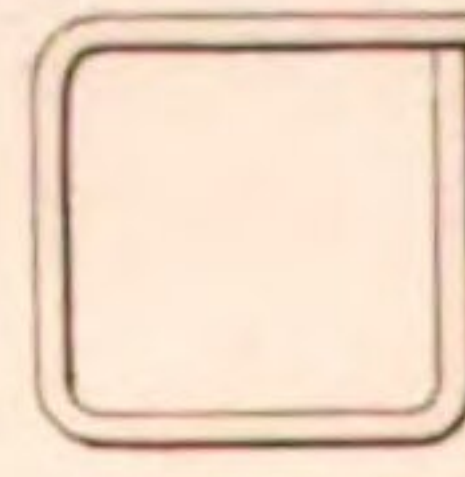
2 Grains.



3 Grains.



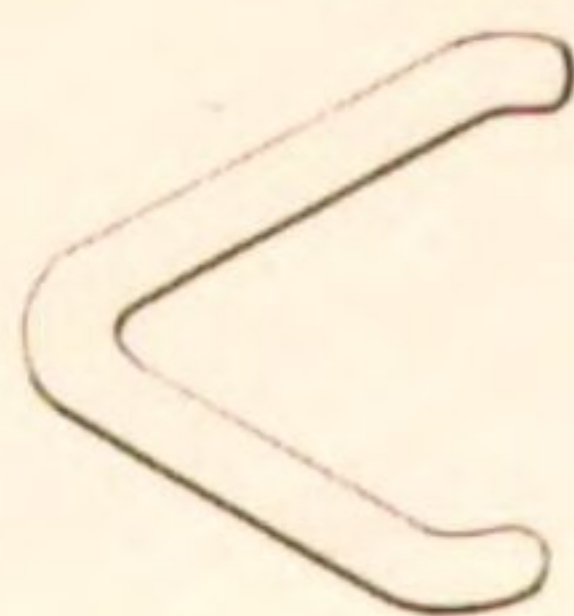
4 Grains.



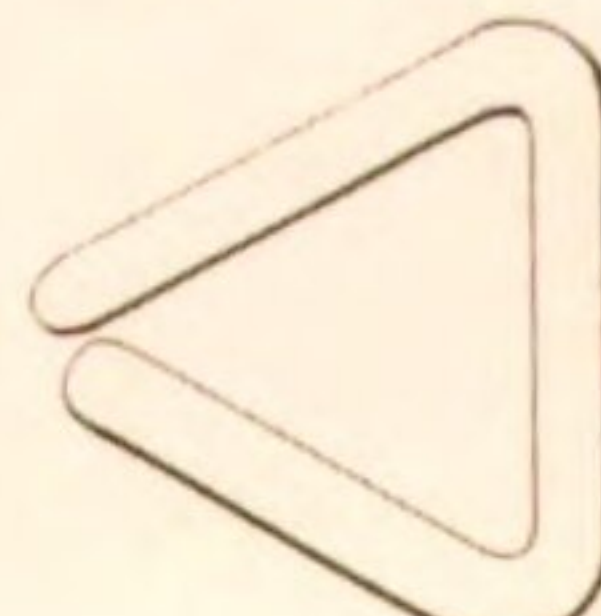
5 Grains.



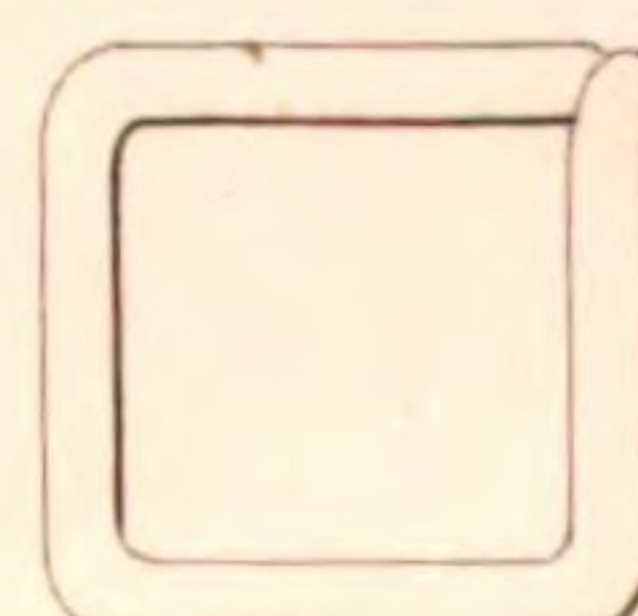
20 Grains.



30 Grains.



40 Grains.



50 Grains.



Dimensions of Weights.

Grains.	Height.	Diameter.	Grains.	Height.	Diameter.
5000	1.60	1.378	500	0.80	0.616
4000	1.45	1.295	400	0.70	0.590
3000	1.30	1.184	300	0.60	0.551
2000	1.15	1.028	200	0.50	0.493
1000	1.00	0.779	100	0.40	0.390

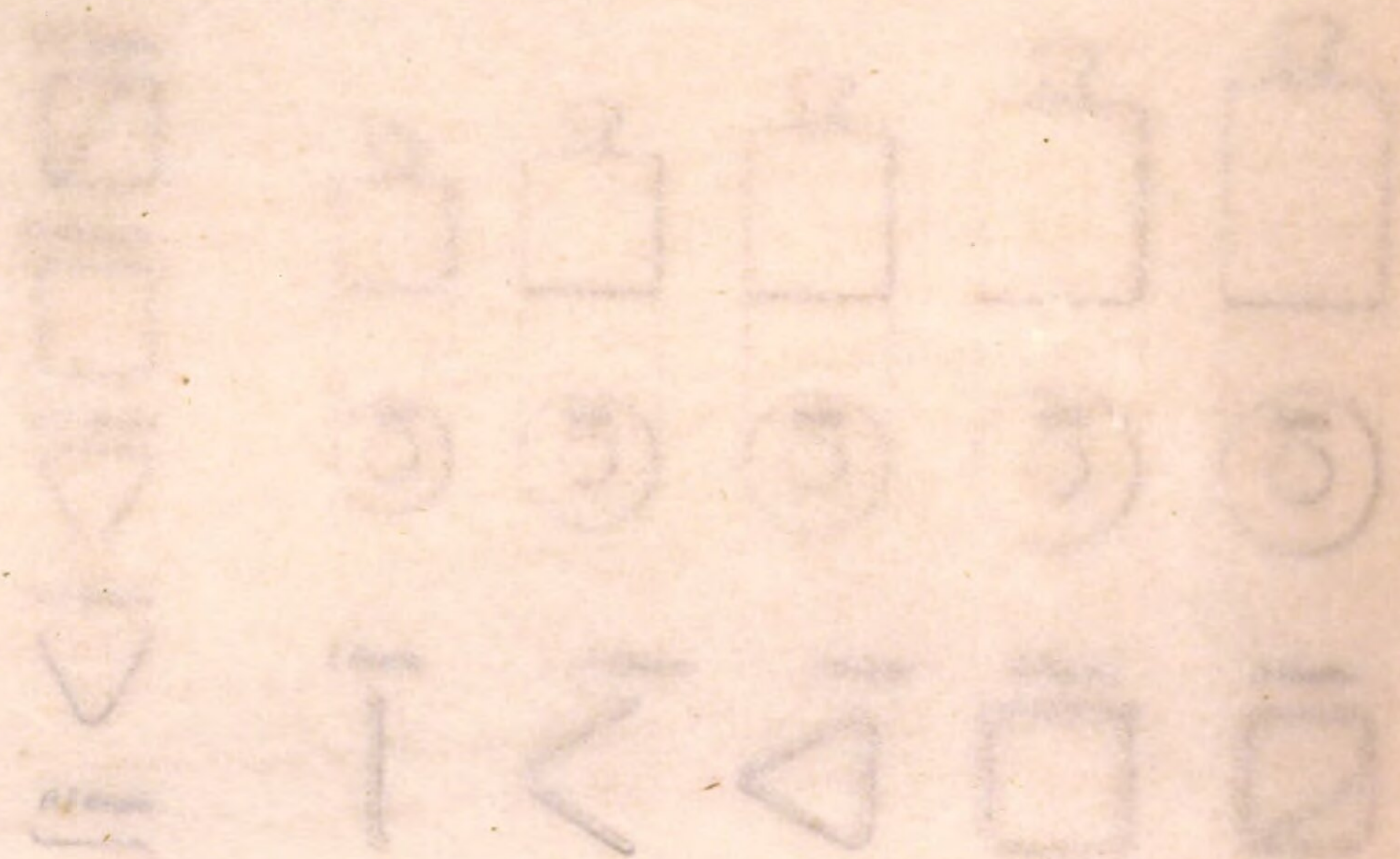
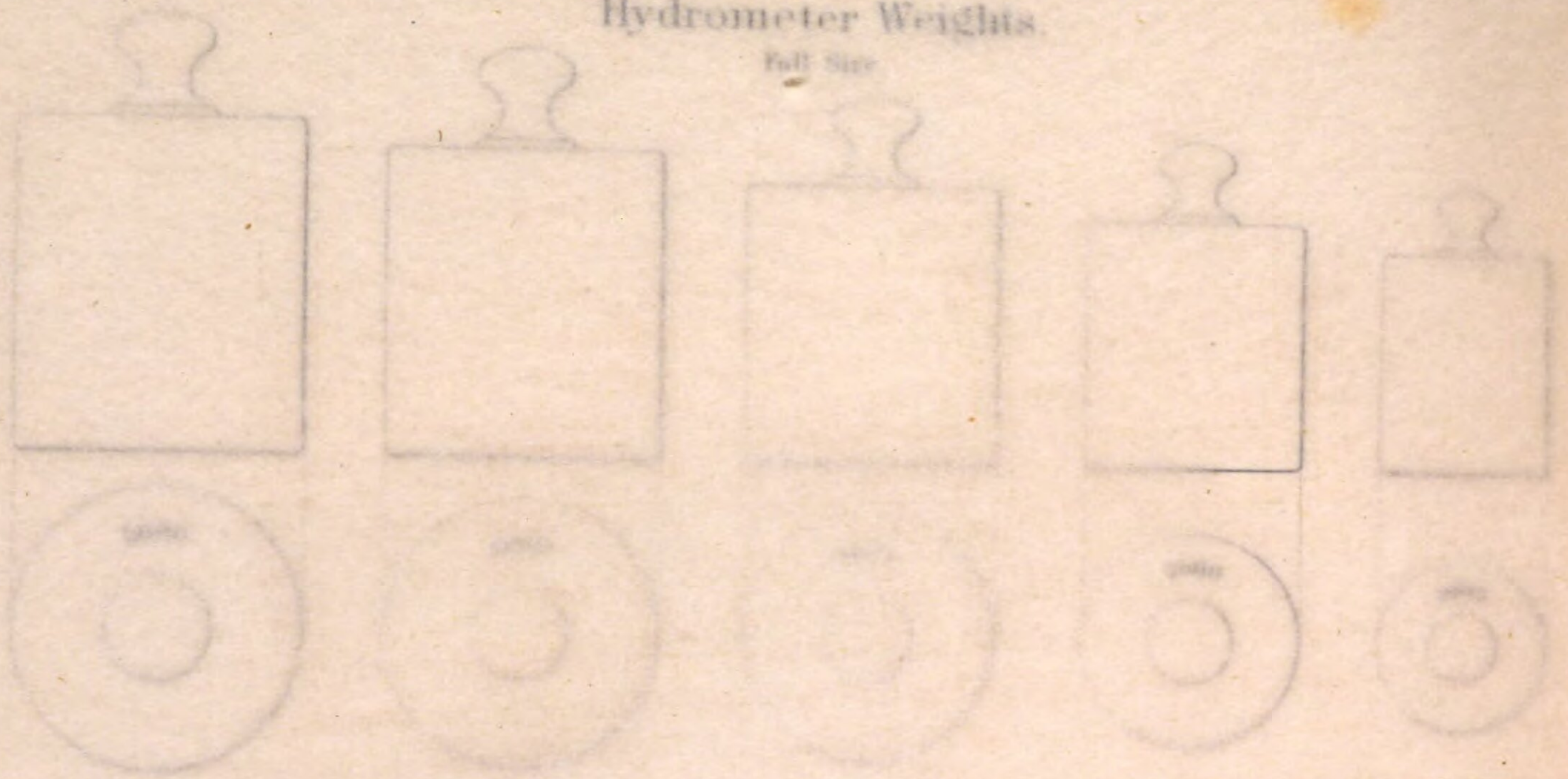
Tens, Brass Wire, Diameter 0.090. Length 0.70.

Units, " " " 0.035. " 0.50.

Tenths, Silver Wire, " 0.010. " 0.40.

Hydrometer Weights.

Full Size



Dimensions of Weights

Grains	Height	Diameter	Grains	Height	Diameter
5000	1.60	1.378	500	0.60	0.500
4000	1.45	1.295	400	0.55	0.450
3000	1.30	1.184	300	0.50	0.400
2000	1.15	1.028	200	0.45	0.350
1000	1.00	0.779	100	0.40	0.300

Tens. Brass Wire, Diameter 0.030

Units. " " " 0.033

Tenths, Silver Wire. " " 0.035

to the plate, the weight pan shall be one-quarter inch above the surface of the water. This will prevent an immersion of the pan when overloaded.

The weight pan is attached to the index stem by an open socket, on its under side, in order that it may be removed with its load, from the hydrometer, and placed on a table, where the weights may be more safely and accurately counted. As the weights do, often, consist of many pieces, errors may occur in the counting, or in the record of them; it is a good precaution to verify them by a re-count, after making the record.

A thermometer, with a scale of about 5° to the inch, and subdivided in quarters of a degree, is suspended in the water while weighing samples, and the temperature is noted at each weighing. The weighings are made at temperatures varying with the state of the weather at the time, and as the density of water varies with its temperature, the latter is noted, in order that the proper correction may be made. The unit adopted, is distilled water at the temperature of 60° Fahrenheit.

The hydrometer may be employed to determine the relative density of distilled, and any other kind of water. The weight of the hydrometer, added to its balance weight in distilled water, at the temperature of 60° , gives the weight of a quantity of pure standard water, which is equal in bulk to the immersed part of the instrument. The weight of the hydrometer, and its load, when immersed in like manner, in any other kind of water at the same temperature, gives the weight of an equal bulk of the latter. And this weight, divided by the former, gives the multiplier for correcting the density, when ascertained in any other than pure distilled water.

Rain, or river water, may be used instead of distilled water, if its relative density be first accurately determined, and the proper correction be made. At the foundries generally, river water is found to be sufficiently pure for use, without needing any correction.

In using the hydrometer, first load the pan with the grain weights until the instrument rests at its zero, and record the sum of these weights, as the *balance of the hydrometer*. Next, place in the pan the sample, together with as many weights as will again bring the instrument to its zero, and record these weights, as the *sample balance in air*. The difference between these balances is equal to the weight of the sample in air. Then place the sample on the bulb of the instrument, and immerse both until the hydrometer again rests at zero, and record the weights on the pan, as the *sample balance in*

water. The difference between this balance and that in air, is equal to the weight of the water displaced by the immersed sample. The temperature of the water, at the time of weighing, is noted, and if it is not at 60° , divide the weight displaced by the sample, by that number in the following table which is opposite the noted temperature, and the quotient will give the corrected displacement for the temperature of 60° . Then, the weight of the sample in air, divided by the corrected displacement, gives the density of the sample.

The hydrometer may be employed in determining the varying density of the same water, at different degrees of temperature. The weight of water it displaces at any other temperature than 60° , divided by its displacement in the same water at 60° , will give the proportionate weight of water displaced by the same instrument, at other temperatures.

The following table has been compiled from Mr. Hassler's Report on Weights and Measures, made to Congress in 1832. He ascertained the weight of water displaced by a given glass bulb, at 215 different temperatures, varying from 32° to 86° Fahrenheit. The weighings were made from time to time, at whatever temperature the chances of the weather gave at the moment. As the results obtained in this form, were not conveniently applicable for common use, they have been reduced to equal divisions of the thermometrical scale, for each quarter of a degree. The reductions were made by marking on a large map the points determined by Mr. Hassler, and by tracing a line through all the points, and then, by measuring this curved line at divisions corresponding to quarter degrees.

The weights given in the table do not represent the absolute density of water at different temperatures, but only the proportionate weights, displaced by the same glass bulb. The varying bulk of the latter in different temperatures, is not taken into account, as it compensates very nearly for the varying bulk of the metals weighed in corresponding temperatures. A column containing the logarithms of the weights, is added to the tables, for convenience in making the computations.

Weight of Distilled Water, displaced by the same Glass Bulb, at different Temperatures.

Temperature.	Weight of water.	Logarithms of weight.	Temperature.	Weight of water.	Logarithms of weight.
32.00	1.000395	0.0001706	45.50	1.000616	0.0002675
32.25	1.000406	0.0001764	45.75	1.000613	0.0002660
32.50	1.000420	0.0001825	46.00	1.000610	0.0002646
32.75	1.000433	0.0001880	46.25	1.000606	0.0002631
33.00	1.000444	0.0001928	46.50	1.000602	0.0002615
33.25	1.000455	0.0001975	46.75	1.000598	0.0002598
33.50	1.000467	0.0002028	47.00	1.000594	0.0002578
33.75	1.000479	0.0002078	47.25	1.000589	0.0002558
34.00	1.000489	0.0002123	47.50	1.000584	0.0002537
34.25	1.000499	0.0002167	47.75	1.000579	0.0002515
34.50	1.000510	0.0002214	48.00	1.000574	0.0002493
34.75	1.000519	0.0002253	48.25	1.000569	0.0002470
35.00	1.000527	0.0002288	48.50	1.000564	0.0002448
35.25	1.000536	0.0002329	48.75	1.000558	0.0002421
35.50	1.000545	0.0002366	49.00	1.000551	0.0002393
35.75	1.000553	0.0002401	49.25	1.000545	0.0002366
36.00	1.000560	0.0002432	49.50	1.000538	0.0002336
36.25	1.000566	0.0002459	49.75	1.000531	0.0002306
36.50	1.000572	0.0002483	50.00	1.000524	0.0002276
36.75	1.000577	0.0002504	50.25	1.000517	0.0002244
37.00	1.000581	0.0002523	50.50	1.000508	0.0002207
37.25	1.000586	0.0002542	50.75	1.000499	0.0002168
37.50	1.000589	0.0002561	51.00	1.000490	0.0002130
37.75	1.000595	0.0002581	51.25	1.000482	0.0002091
38.00	1.000599	0.0002603	51.50	1.000472	0.0002050
38.25	1.000604	0.0002622	51.75	1.000462	0.0002007
38.50	1.000609	0.0002642	52.00	1.000452	0.0001961
38.75	1.000614	0.0002666	52.25	1.000441	0.0001915
39.00	1.000619	0.0002685	52.50	1.000430	0.0001869
39.25	1.000628	0.0002725	52.75	1.000419	0.0001821
39.50	1.000635	0.0002755	53.00	1.000409	0.0001775
39.75	1.000642	0.0002786	53.25	1.000398	0.0001727
40.00	1.000646	0.0002806	53.50	1.000387	0.0001679
40.25	1.000649	0.0002817	53.75	1.000374	0.0001625
40.50	1.000650	0.0002821	54.00	1.000363	0.0001574
40.75	1.000650	0.0002821	54.25	1.000349	0.0001515
41.00	1.000649	0.0002819	54.50	1.000337	0.0001465
41.25	1.000649	0.0002815	54.75	1.000322	0.0001398
41.50	1.000647	0.0002810	55.00	1.000307	0.0001348
41.75	1.000645	0.0002802	55.25	1.000296	0.0001286
42.00	1.000644	0.0002796	55.50	1.000282	0.0001223
42.25	1.000543	0.0002792	55.75	1.000267	0.0001161
42.50	1.000642	0.0002787	56.00	1.000254	0.0001103
42.75	1.000641	0.0002781	56.25	1.000239	0.0001040
43.00	1.000639	0.0002774	56.50	1.000224	0.0000973
43.25	1.000637	0.0002766	56.75	1.000209	0.0000910
43.50	1.000635	0.0002756	57.00	1.000195	0.0000846
43.75	1.000633	0.0002748	57.25	1.000181	0.0000783
44.00	1.000631	0.0002740	57.50	1.000165	0.0000717
44.25	1.000629	0.0002731	57.75	1.000148	0.0000644
44.50	1.000626	0.0002721	58.00	1.000133	0.0000579
44.75	1.000624	0.0002710	58.25	1.000118	0.0000512
45.00	1.000621	0.0002699	58.50	1.000101	0.0000439
45.25	1.000619	0.0002687	58.75	1.000085	0.0000368

Weight of Distilled Water at different Temperatures—Continued.

Temperature	Weight of water.	Logarithms of weight.	Temperature.	Weight of water.	Logarithms of weight.
59.00	1.000068	0.0000296	72.75	0.998855	1.9995027
59.25	1.000051	0.0000222	73.00	0.998825	1.9994892
59.50	1.000034	0.0000149	73.25	0.998795	1.9994765
59.75	1.000017	0.0000072	73.50	0.998766	1.9994635
60.00	1.000000	0.0000000	73.75	0.998736	1.9994506
60.25	0.999981	1.9999919	74.00	0.998705	1.9994373
60.50	0.999963	1.9999839	74.25	0.998675	1.9994241
60.75	0.999945	1.9999760	74.50	0.998645	1.9994113
61.00	0.999927	1.9999681	74.75	0.998615	1.9993979
61.25	0.999909	1.9999603	75.00	0.998584	1.9993845
61.50	0.999890	1.9999522	75.25	0.998553	1.9993710
61.75	0.999871	1.9999440	75.50	0.998521	1.9993574
62.00	0.999853	1.9999361	75.75	0.998492	1.9993446
62.25	0.999834	1.9999280	76.00	0.998461	1.9993313
62.50	0.999814	1.9999193	76.25	0.998430	1.9993175
62.75	0.999795	1.9999108	76.50	0.998399	1.9993039
63.00	0.999774	1.9999020	76.75	0.998367	1.9992904
63.25	0.999753	1.9998929	77.00	0.998337	1.9992771
63.50	0.999733	1.9998840	77.25	0.998309	1.9992649
63.75	0.999712	1.9998749	77.50	0.998278	1.9992515
64.00	0.999692	1.9998660	77.75	0.998248	1.9992382
64.25	0.999672	1.9998574	78.00	0.998216	1.9992244
64.50	0.999651	1.9998483	78.25	0.998184	1.9992104
64.75	0.999629	1.9998388	78.50	0.998152	1.9991965
65.00	0.999608	1.9998294	78.75	0.998120	1.9991826
65.25	0.999585	1.9998198	79.00	0.998080	1.9991686
65.50	0.999563	1.9998104	79.25	0.998055	1.9991545
65.75	0.999542	1.9998011	79.50	0.998022	1.9991400
66.00	0.999521	1.9997918	79.75	0.997989	1.9991258
66.25	0.999499	1.9997822	80.00	0.997956	1.9991113
66.50	0.999479	1.9997737	80.25	0.997923	1.9990970
66.75	0.999454	1.9997630	80.50	0.997889	1.9990822
67.00	0.999432	1.9997533	80.75	0.997855	1.9990673
67.25	0.999409	1.9997435	81.00	0.997821	1.9990526
67.50	0.999387	1.9997338	81.25	0.997788	1.9990383
67.75	0.999365	1.9997243	81.50	0.997754	1.9990233
68.00	0.999343	1.9997146	81.75	0.997718	1.9990079
68.25	0.999320	1.9997047	82.00	0.997681	1.9989918
68.50	0.999297	1.9996945	82.25	0.997644	1.9989756
68.75	0.999273	1.9996843	82.50	0.997607	1.9989596
69.00	0.999249	1.9996740	82.75	0.997571	1.9989438
69.25	0.999226	1.9996636	83.00	0.997536	1.9989286
69.50	0.999202	1.9996532	83.25	0.997500	1.9989138
69.75	0.999178	1.9996427	83.50	0.997468	1.9988989
70.00	0.999153	1.9996320	83.75	0.997433	1.9988837
70.25	0.999127	1.9996208	84.00	0.997398	1.9988684
70.50	0.999102	1.9996098	84.25	0.997363	1.9988532
70.75	0.999076	1.9995985	84.50	0.997327	1.9988378
71.00	0.999050	1.9995873	84.75	0.997292	1.9988223
71.25	0.999024	1.9995779	85.00	0.997256	1.9988068
71.50	0.998997	1.9995642	85.25	0.997220	1.9987908
71.75	0.998969	1.9995522	85.50	0.997183	1.9987750
72.00	0.998942	1.9995401	85.75	0.997150	1.9987604
72.25	0.998912	1.9995274	86.00	0.997116	1.9987456
72.50	0.998884	1.9995150			

The gun is first weighed in air, and then, without removing it from the slings, all are lowered down by the crane, until the gun is wholly immersed in water, which is contained in the cistern beneath. In this weighing, a part of the gun is in air, and both parts act in affecting the weights employed to adjust the balance.

WEIGHING SCALES FOR BRONZE GUNS.

The Weighing Scales usually employed at the foundries, are not sufficiently sensitive for ascertaining the specific gravity of bronze guns. A weighing balance was, therefore, constructed for the purpose, a drawing of which, PLATE XXI, is annexed. It is made portable, in order that it may be safely transported to different foundries, without inconvenience. The balance is packed in one case, and the weights in another. It is designed to bear 2,000 pounds, and will therefore weigh the heaviest bronze guns.

The graduated arm of the balance is 50 inches long, from the fulcrum to the knife edge at the end, and is divided into 500 equal parts, of one-tenth inch each. The knife edge in the short arm, is 2.5 inches from the fulcrum, making the proportion of the two arms, as 20 to 1. The weights are suspended from the knife edge at the end of the long arm. A light chain with hooks, is attached to one of the weights, and forms a part of it. Other weights are hooked upon this chain. The graduated edge of the arm is in the same plane with the knife edges. It is straight and smooth, not notched; the divisions being marked on the side of the arm, as on a scale. A small weight, one-fourth of a pound, is made to slide along on the upper edge of the arm. This balances a weight of 5 pounds, when at the extremity of the arm, and gives to each division, a value of a hundredth part of a pound.

The balance is suspended in a yoke, having, in one end, an aperture which receives the large arm of the balance, and restricts its oscillation within narrow limits. To this part of the yoke is attached a hinged index, which points to a horizontal line on the arm, when the balance is justly equipoised. In weighing guns, the yoke is attached to a crane, and the gun is suspended from the lower hook of the balance, by two loops, or slings, made of brass wire. One of them is placed in rear of the trunnions, and the other in front of them, and they are so spread apart, on the under side of the gun, that its upper surface will be horizontal when suspended. This gives a little inclination to the axis of the gun, and allows a free escape of air from the bore and vent, when the gun is immersed.

The gun is first weighed in air, and then, without removing it from the slings, all are lowered down by the crane, until the gun is wholly immersed in water, which is contained in the cistern beneath. In this weighing, a part of the brass wire slings is immersed, and a part remains in air, and both parts act in affecting the weights employed to adjust the balance, making the displacement greater than is due to the gun alone. To make the necessary corrections for the weight of the slings, it is found most convenient to balance them by any suitable counterpoise, made to slide along on the graduated arm. The positions of the counterpoise, when it balances the slings when in air, and when they are partly immersed, are noted; and care is taken to place the counterpoise in the same positions, when weighing the gun in air, and in water. The weight of the slings is thus neutralized in both cases, without resorting to any additions or subtractions, to or from, the weights counted.

The slings should be immersed to the same point, in each weighing; so that the displacement shall be equal, in every case, to that which the counterpoise balances.

As a large quantity of water is required in these weighings, it will not be convenient to obtain pure water, by distillation. It may, therefore, be necessary to employ impure water. When such water is used, its relative density compared with distilled water, should be first ascertained by employing the hydrometer, as described in a preceding page. The proper correction for impure water may then be made.

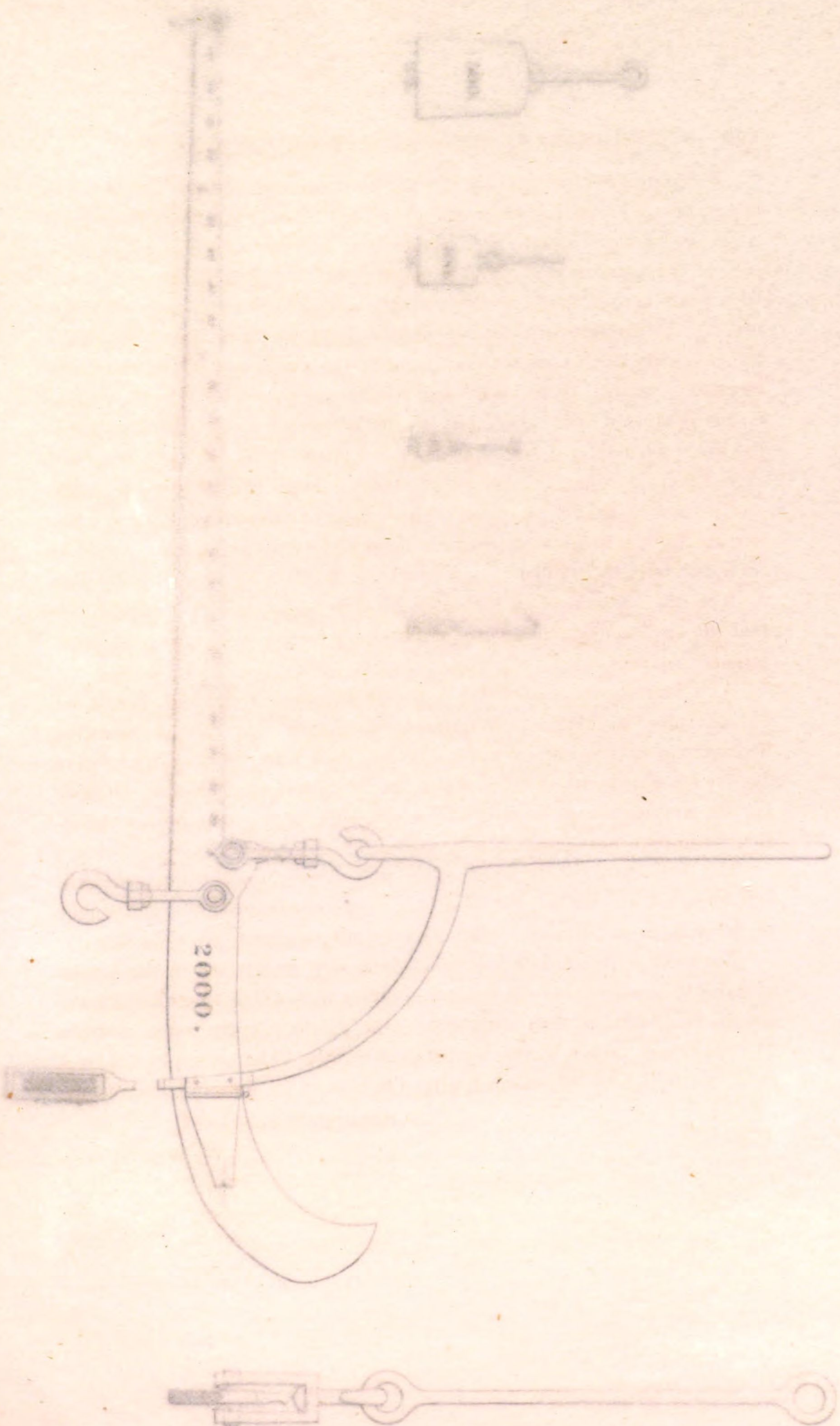
The temperature of the water, at the time of weighing the immersed gun, is to be noted, and the displacement to be corrected accordingly. The weight of the gun, in air, divided by the corrected displacement, gives the density.

The cubic contents of each gun, may be readily ascertained by the weight of water it displaces, and the general accuracy with which a number of guns are finished, may be thus compared. One pound of pure water contains 27.72645 cubic inches, at the temperature of 60°. The corrected displacement, multiplied by this number, gives the bulk of the gun, in cubic inches.

Respectfully submitted,

W. WADE.

Balance for Weighing Bronze Guns.



The gun is first weighed in air, and then, without removing it from the slings, it is lowered down by the crane, until the gun is wholly immersed in water, which is contained in the crane beneath. In this weighing, a part of the gun and slings is immersed, and a part remains in air, and care must be taken in adjusting the weights employed to adjust the balance, making the difference between the two weighings due to the gun alone. To make the correction for the weight of the slings, it is found most convenient to employ a small and suitable counterpoise, made to slide along the graduated arm. The position of the counterpoise, when it balances the slings alone, is noted, and when they are partly immersed, are noted, and care is taken to place the counterpoise in the same positions, when weighing the gun in air, and in water. The weight of the slings is then calculated, and in both cases, without resorting to any additions or subtractions, is obtained, the weights corrected.

The slings should be immersed to the same point, in each weighing, so that the displacement shall be equal, in every case, to that which the counterpoise balances.

As a large quantity of water is required in these weighings, it will not be convenient to obtain pure water by distillation. It may, therefore, be necessary to employ impure water. When such water is used, its relative density compared with distilled water should be ascertained by employing the hydrometer, as described in a preceding page. The proper correction for impure water may then be made.

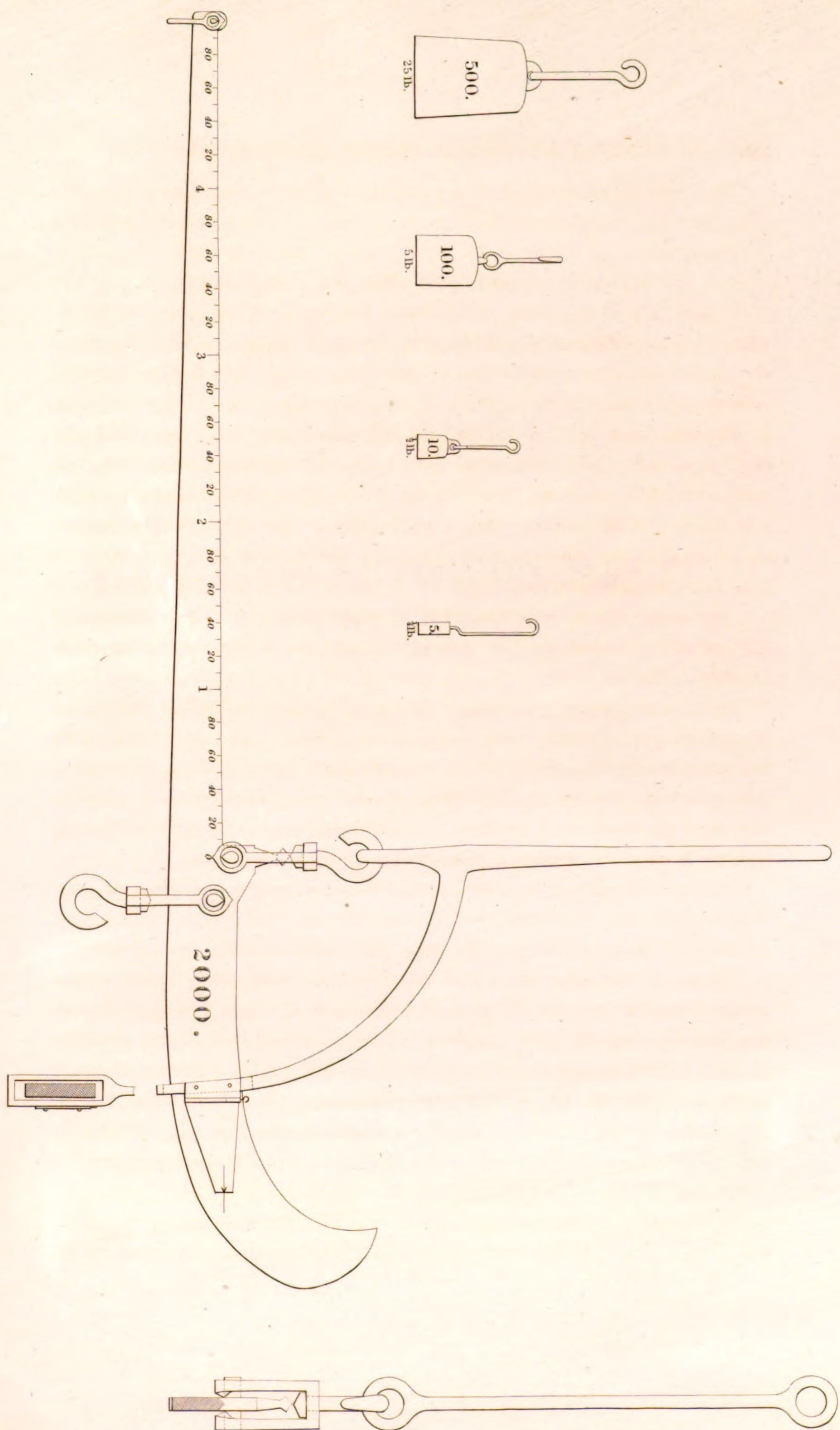
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Respectfully submitted,

W. WADK.

Balance for Weighing Bronze Guns.



Scale, & Size.

Designed by W. Wade.

FINAL REPORT.

REPORT

OF

EXPERIMENTS TO TEST THE IRON CANNON

AT THE

SEVERAL FORTS AND ARSENALS.

BY

LT. L. A. B. WALBACH.

JUNE, 1847.

1990

FINAL REPORT,

OF THE

EXAMINATION OF THE QUALITY OF CAST-IRON CANNON IN
SERVICE, BY LT. L. A. B. WALBACH, ORDNANCE.

BALTIMORE, *June 30, 1847.*

SIR: THE experiments for testing the strength and quality of the cannon, at the several Forts and Arsenals throughout the United States, have within the past year been completed.

This duty has been continually in progress since the spring of 1845, during which time the specific gravity and tensile strength of samples, from 2,808 cannon of different calibres, have been determined, and the cannon themselves classified in accordance with the quality of the metal, as exhibited under the tests applied.

The order of the experiments, connected with this re-examination of the cannon in service, has been as follows:

PROGRAMME OF EXPERIMENTS.

1st. The determination of the specific gravity of a sample taken from the muzzle of each gun. 2d. The determination also of its tensile strength. 3d. An examination of the surface of fracture, with a description of its color, structure, and any peculiarity of character that might present itself; and 4th. A subsequent proof to extremity by gunpowder and hydrostatic pressure, of certain cannon affording, under the tests applied, results of a doubtful nature;—as yet but partially applied.

Proper machines having been provided, the first trials for this purpose were made during the spring of 1845, with the cannon at Fort Monroe, Virginia. The results obtained from the 574 guns at this Post, were satis-

factory and interesting; and were deemed sufficiently so by the Department, to justify the prosecution of a similar mode of examination with the others in service.

A great difference was observed in the character of the metal of different guns, as well in strength, and density, as in the appearance presented by the fracture: the quality of the cannon was found also to depend upon the values exhibited by these tests; and it became necessary therefore to establish a system of Classification, by which they could be properly arranged and designated. To do this it was required, in the first place, to define the lowest limit of strength admissible to a gun of the *first* class; next, to determine the highest limit of such as were to be rated to a *third* class, while all others, of an intermediate quality, would then properly come under the head of an intervening or *second* class.

By referring to the experiments on the tenacity of the iron cannon recently cast at Boston, under the Revised Regulations, the lowest strength therein recorded, was found to be 24,500 lbs. to the square inch; and as these guns were doubtless of a superior quality, any value above that limit, was deemed compatible with safety. My own trials, confirmed by proofs to extremity, enabled me to determine the quality of such as were to be rated to the inferior grade. The three classes, which have thus been arranged, may be therefore defined, as follows:

The *First Class* comprises all such cannon as afforded to a certain value of strength and density, a corresponding character of fracture. They possessed, it was thought, sufficient strength and endurance to be regarded as among the best in service of their date.

The *Second Class* included those which, though above the limit of the third class, are either deficient in one or more of the properties required for the first class, or involved some case of discrepancy or doubt; while under the head of a *Third Class* were arranged such as exhibited an inferior quality of metal.

A condensed statement of the account of work done since the commencement of the experiments, is contained in the following table, which exhibits also the present condition of the armament of the Sea Coast.

[illegible]

In addition to the foregoing, several trial guns and cannon, of foreign manufacture, have also been tested; which, together with duplicate samples taken from some of the guns where there was a doubt, or chance for error, will probably make the number of experiments to exceed 3,000.

To collect the samples of the 2,808 cannon, scattered as they were throughout the country—to transport the heavy machines required for that purpose—to mark the specimens, with the number and calibre of the guns from which they were taken, and to reduce them, under the lathe, to the proper form and dimensions, preparatory to trial, has consumed a considerable portion of the time allotted to the experiments.

The cavity or perforation left in the face of the muzzle by the abstraction of the trial sample has, in every instance, been filled with a composition of sal ammoniac and iron turnings, compactly driven in the moist state. This filling leaves no trace of disfiguration on the surface of the gun, and, as has been previously reported, sustains both the effects of weather and the heaviest shocks of firing uninjured.

The following abstract from table No. 1 will exhibit the general classification of the cannon in service, cast prior to the revised system of 1840:

TABLE II.—*General Classification of Cannon in Service.*

1st. class	1239	44.124 per cent.
2d. class	932	33.191 “
3d. class	637	22.685 “
Total	2808	100.000

With regard to the guns of the second class, of which it appears there are about 33 per cent., it should be remarked, that in quality they are equal to several of the foreign cannon lately procured by the United States, and although not so good as those of their own date, which have been arranged to the first class, they are still considered serviceable, and in certain positions, as on fronts not liable to attack, may remain with security until conveniently replaced.

Nearly one-half, or 44 per cent. of the guns thus re-examined, have rated to the first class; they are reported as among the best in service of their date, though not of that uniformly superior character, belonging to those cast by the Ordnance Department under their present revised regulations.

The several private foundries of West Point, Pittsburg, Georgetown,

D. C., and Bellona, near Richmond, have been employed at different periods, from 1827 to 1840, in casting the 2,808 cannon thus reported.

A marked difference is perceptible in the quality and appearance of the metal from the different foundries, and it seems as if there belonged to each a peculiar type, or character of fracture, to distinguish it from the rest. For instance, the guns of the Bellona Foundry are generally of a high mottle, with the lighter portions of the mottle of a silvery white color. The character of those from the Columbian Foundry are also of a mottle, rather high, but less so than the guns of the Bellona Foundry, and also with less of the silvery aspect; the metals of both foundries is accompanied by a high degree of density.

The guns from the West Point Foundry are of a darker mottle, with the fracture inclining to a gray or a mottled gray; the value of their specific gravity is not so high as the foregoing, but the metal still possesses a fair average density.

The samples of the cannon from the Pittsburg Foundry present a still darker gray, with little or none of the mottled aspect, and appear highly carbonaceous; the specific gravity of the metal being correspondingly low.

In general terms, the appearance of the metal from the different foundries may be summed up in two divisions, thus: Columbia and Bellona Foundry guns—mottled iron; West Point and Pittsburg guns—gray iron. The locality from which the metal was drawn has no doubt influenced the result, modified, also, by the different modes of treatment at the several foundries.

In seeking for the character of fracture most desirable for gun metal, we would look for it between the lower mottle of the Columbia, and the higher gray of the West Point Foundry, passing over the extreme values of the Bellona and Pittsburg iron. This fracture may, therefore, best be defined as follows: a soft, uniform mottle, passing into a light or bright gray, the spots of the mottle being so intimately blended, and so nearly of the same hue, as to give the fracture a light or bright gray aspect.

The cannon furnished by the South Boston Foundry have all been cast since the revised regulations of 1840, and are not, therefore, included in the foregoing. The few trials that I have made of guns from this foundry, have afforded the most favorable results, and the quality of the metal is unsurpassed.

It seems, therefore, unnecessary to submit these guns to any re-exami-

nation, beyond that required by the reception proof. The same remark would also apply to the cannon cast at the other Foundries since the establishment of the Revised Regulations—as all seem now to furnish a greatly improved and superior quality of metal.

TABLE III.—*Extract from the Record-book of the Experiments made to Test the Strength*

Calibre.	No. of guns.	Initials of inspectors.	Initials of founder and foundry.	Date of casting.	Weight of gun.	Specific gravity.	Tensile strength; number of pounds to the square inch.	Class.	Location.
Pounders.									
32	10	J. B.	McC. P. & W. P., P. F.	1832	7405	7.23	29196	1	Fort Morgan.
32	12	"	" "	1832	7413	7.22	31029	1	Fort Morgan.
32	13	"	" "	1832	7485	7.21	29913	1	Fort Pickens.
32	225	J. W. R.	" "	1839	7534	7.06	13399	3	Baton Rouge arsenal.
32	229	"	" "	1839	7544	7.04	16925	3	Alleghany arsenal.
32	230	"	" "	1839	7518	7.07	16925	3	Alleghany arsenal.
32	10	J. B.	J. M., C. F.	1829	7526	7.24	26093	1	On skids outside Fort McHenry.
32	20	"	"	1829	7561	7.27	28913	1	Fort Moultrie.
32	29	"	"	1829	7449	7.22	27926	1	In battery, Fort McHenry.
24	303	J. W. R.	"	1840	7480	7.15	20733	2	Washington arsenal.
24	305	"	"	1840	7490	7.14	19746	2	Washington arsenal.
24	310	"	"	1840	7584	7.12	20310	2	Washington arsenal.
32	10	J. B.	J. C., B. F.	1829	7558	7.228	27221	1	Fort Monroe, Va.
32	14	"	"	1829	7552	7.206	28208	1	Fort Monroe, Va.
32	40	"	"	1829	7530	7.259	28631	1	Fort Monroe arsenal.
32	448	J. W. R.	"	1839	7552	7.08	17630	3	Fort Monroe arsenal.
32	449	"	"	1839	7566	7.12	17489	3	Fort Monroe arsenal.
32	450	"	"	1839	7566	7.108	17348	3	Fort Monroe arsenal.
32	2	J. B.	W. P. F.	1829	7403	7.22	29196	1	Fort Lafayette, N. Y.
32	26	"	"	1829	7508	7.29	28208	1	Fort Columbus, N. Y.
32	33	"	"	1829	7504	7.19	26799	1	Ellis's Island, New York harbor.
32	325	J. W. R.	"	1839	7450	7.024	19464	3	Fort Columbus, N. Y.
32	332	"	"	1839	7478	7.026	19323	3	Fort Columbus, N. Y.
32	335	"	"	1839	7443	7.024	19323	3	Ordnance department, Governor's Island, N. Y.
32	1	W. M.	"	1841	6933	7.214	28208	1	Ordnance department, Governor's Island, N. Y.
32	2	"	"	1841	6933	7.22	28349	1	Ordnance department, Governor's Island, N. Y.
32	3	"	"	1841	6975	7.23	28641	1	Ordnance department, Governor's Island, N. Y.

In connection with this duty, a record has been kept of every trial made since the commencement of the experiments. The following Table, extracted from the Record-book, will show the manner in which every fact, with its accompanying result, has been registered.

and Quality of the Cast Iron Cannon at the several Forts and Arsenals in the United States.

Color.	Fracture.	Structure.	Aspect of turned surface.	Remarks.
A uniform bright and light gray.	Very close, short, and regular.	Of fine and closely compacted structure.	Very smooth.	These guns were cast at the Pittsburgh Foundry.
Light gray, uniform, and inclining to bright.	Very close, short, and regular.	Of fine and closely compacted structure.	Very smooth.	
Light gray, uniform, and inclining to bright.	Very close, short, and regular.	Of fine and closely compacted structure.	Very smooth.	
Very dark gray.	Very hackly.	Coarse and irregular.	Remarkably pitted.	
Dark gray, with shining crystals.	Hackly and jagged.	Coarse and open.	Pitted.	
Dark gray, with shining crystals.	Hackly and jagged.	Coarse and open.	Pitted.	These guns were cast at the Columbia Foundry.
Of a high mottle, and with the white of a silvery cast.	Short.	Compact.	Smooth.	
Regular mottle.	Short and close.	Very compact.	Smooth.	
Of a high mottle, like No. 10.	Short and even.	Compact, and fine grained.	Smooth.	
Mixed mottle.	Rather uneven.	Somewhat uneven.	Rather pitted.	
Mixed mottle.	Rather uneven.	Somewhat uneven.	Rather pitted.	These guns were cast at the Bellona Foundry.
Mixed iron, and carbonaceous.	Rough.	Coarse and irregular.	Not much pitted.	
High mottle, inclining to silvery.	Close and short.	Compact and regular.	Smooth, with a mottle aspect.	
Uniform mottle; rather high.	Close and short.	Compact and regular.	Smooth, with a mottle aspect.	
Mottle very uniform, and of a high white.	Short, close, and even.	Fine grained, compact, and even.	Smooth, with a mottle aspect.	
Dark gray, with coarse and large stellated crystals.	Rough, uneven, and hackly.	Coarse, open, and irregular.	Much pitted, with large stellated cavities.	These guns were cast at the West Point Foundry.
Mottle, passing into a light gray.	Close and even.	Compact, and fine grained.	Smooth, and without cavities.	
Mottle, passing into a light gray.	Close and even.	Compact, and fine grained.	Smooth, and without cavities.	
Uniform gray mottle.	Close and even.	Compact, and fine grained.	Smooth, and without cavities.	
Dark gray, with large stellated crystals.	Hackly, rough, and uneven.	Open, coarse, and irregular.	Much pitted, with large stellated crystals.	
Dark gray, with large brilliant crystals.	Hackly and jagged.	Open, coarse, and irregular.	Uneven, and much pitted.	These guns were cast at the West Point Foundry.
Dark gray, black, and carbonaceous.	Hackly and jagged.	Open, coarse, and irregular.	Uneven, and much pitted.	
Uniform mottle, with the spots so blended as to pass into a light, soft gray.	Close, smooth, and even.	Compact, regular, and fine grained.	Very smooth, and free from cavities.	

The facts and details of each separate trial, as thus recorded, will comprise a volume of some 200 pages.

It is intended to deposit this record in the Ordnance Office, where, as a book of reference, it will furnish any desired information relative to the character, history, location, and quality of every cannon in service. Aided by the samples which have been preserved for this purpose, and with the record of the facts of each case before them, the Department will have the means of determining the correctness of my own conclusions, and of deciding upon the final disposition to be made of the several cannon thus examined.

The samples have been arranged in cabinet form, in the order of their calibre and dates, under the heads of the respective foundries at which they were cast; and thus spread out, will afford a specimen of the metal of every gun in service. The distinctive character of fracture peculiar to each foundry, as before noted, is readily observed; and even where a change of date, or contract, takes place at the same foundry, or where a different kind of iron has been used, or a new system introduced, a corresponding change is evident in the different appearance presented by the fracture of the metal.

It would be well if the samples thus arranged were deposited in the Model Office at the Washington Arsenal, with a copy also of the Record-book, where for the sake of reference, they might at some future period be found useful.

In submitting the present annual report, which closes the experiment for the re-examination of the heavy ordnance of the United States, it has been thought proper to embody all such facts hitherto reported, as serve to prove the utility and value of this mode of testing the quality of cannon. A recapitulation of some of the most important of them has been prepared for this purpose, and is hereto annexed.

RECAPITULATION.

1. Facts, indicating the value of this method for testing the quality of the cannon, and confirming the correctness of the results.

1st. During the examination of the cannon at Fort Monroe, Virginia, in the spring of 1845, it occurred that in a series of 32 pounders, numbered by the inspector from 354 to 370, inclusive, and cast at the Bellona Foundry, eight of the seventeen, or nearly 50 per cent., were not on hand. The result of the trials upon the nine others showed that not one of them could be rated as a First Class gun. The Officer in charge having informed me that

none of the guns of that series had been issued from his post, it became necessary to refer to the Department for information in the matter, and on the records of the Ordnance Office the following account of these missing guns was found:—

Extract from the Report of the Inspectors of Ordnance, dated August 7, 1834.

No. of gun.	BURST.		Remarks of the Inspectors.
	1st. fire of the proof.	2d. fire of the proof.	
354	1	—	The founder ascribes the failure of his guns to excessive proof charges. The Inspectors entertain a different opinion, and ascribe the result to a defect, either in the metal, or in the manner of working it, in which they were sustained by the nature of the fractures. Specimens were preserved, and have been since submitted to experienced founders, who, without knowing the circumstances, or whence they came, at once decided that the metal was good, but had been injured, and rendered unfit for gun metal, in melting and casting. That the result arises from this cause cannot be doubted, when it is remembered that the cannon at the other foundries are subjected to the like proof, and for the last year without failure.
355	Sustained	the proof.	
356	Sustained	the proof.	
357	1	—	
358	1	—	
359	Sustained	the proof.	
360	1	—	
361	Sustained	the proof.	
362	Sustained	the proof.	
363	Sustained	the proof.	
364	Sustained	the proof.	
365	1	—	
366	Sustained	the proof.	
367	—	1	
368	Sustained	the proof.	
369	1	—	
370	1	—	

W. J. WORTH,

Major of Ordnance and Inspector.

WM. MAYNADIER,

Lieutenant and Assistant Inspector.

The foregoing contains, within itself, an almost entire chapter of facts. 1st. It appears that the eight missing guns had all burst during proof, and seven of them at the very first fire. 2d. That although the other nine did sustain the proof, yet, without the knowledge of the foregoing facts, they were, eleven years afterwards, on the application of the tests in question, decided to be of bad or doubtful quality. They were no doubt of the same material, cast under the same system, and also at the same time with the others, though by accident, possibly, had just strength enough to sustain this proof, although, in my opinion, they were not sufficiently strong to stand the few next fires of the service charge. I have, therefore, classed them as

unservicable, not doubting the correctness of this decision will at some subsequent period be practically and satisfactorily proved. 3d. This case confirms the necessity of the Order of 1840, which requires the rejection of the entire order or contract, when 25 per cent. of the number furnished shall have failed under the proof. 4th. It is evident, that, under the present proof by powder, though some of the worst guns may burst, yet others will pass into the service incapable of sustaining even a moderate degree of firing. It is also apparent that, had the method I am now employing been in use at that period, not one of the guns in question would have been received from the founder; and this consideration has suggested to me the substitution of a more direct and practical test instead of the proof by powder, which suggestions I have already noticed in a previous report.

2d. Having had occasion to visit the West Point Foundry on duty, in August, 1845, I mentioned to the proprietor that certain of his cannon afforded, under the tests applied, every indication of an inferior quality. At his request, I gave him the number of the cannon, which were marked from No. 308 to 337, inclusive. On referring to the records of the foundry, the following appeared on his books: "32 pounders, No. 308 to 337 (the identical guns inspected April, 1839), *hot blast iron*." Here I had, by trial merely upon the specimens taken from the cannon, given him, from among several hundred others, the first and last gun of a certain order or contract; all of which I had decided to be of bad or doubtful quality, and which the foundry records acknowledged to have been cast from hot blast iron; a material, the use of which has since been wisely prohibited. As a further argument in the case, it appears, from my own books, that gun No. 308, the first of this order, gave under trial a specific gravity of 7.09, and a tensile strength of 20,732 lbs. to the square inch, while No. 307, the gun next preceding it in the series, gave a density of 7.185, and a strength of 25,246 lbs. per square inch. Gun 307, it seems, was cast in 1834, and before the use of hot blast iron at the foundry; while gun No. 308, cast five years subsequent thereto, was acknowledged to have been fabricated from this obnoxious material.

3d. While engaged in testing the quality of the cannon in the harbor of New York, I found among a series of 42 pounders, cast in 1842, at the West Point Foundry, one differing very widely from the quality of the others. Here were 20 cannon all cast under the Revised Regulations, and

under the supervision of an experienced officer, the samples from 19 of them giving the highest values of strength and density, and rated accordingly to the first class; while one of them, numbered 18 in the series, afforded every indication of an inferior quality of iron. In fact, Nos. 17 and 19, the guns immediately preceding and following it in the series, gave as follows: No. 17, a density of 7.23 and a tenacity of 28,631 lbs. per square inch, and No. 19, a density of 7.24, and a tenacity of 29,619 lbs., while gun No. 18 gave the very low density of 7.02, with the corresponding low tenacity of 19,323 lbs.; a difference, it appears, of 10,000 lbs., nearly, in the relative strength of these guns.

This fact seemed at once to disprove the accuracy of the system: it was, to say the least, an anomaly, and as such I reported the circumstance to the Department. It was supposed at first that I had made an error in marking the specimen, and that it might possibly belong to some gun other than 42 pounder No. 18, of 1842; but being positive to the contrary, I was allowed to refer to the files of the Ordnance Office, where, upon the report of the Inspector, the following remarks appeared opposite to this gun, No. 18.

Extract from the inspection report of Major R. L. Baker, of twenty 42 pounder guns at the West Point Foundry, dated March 9, 1842:

"No. 18 is reported by the attending officer to have about 20 inches of *bad iron at the muzzle end*, caused by a deficiency of good metal in the furnace."

"Had this inferior quality extended lower down, or been nearer the seat of the charge, the gun would have been rejected: but being quite near the muzzle, it is not apprehended that the gun can be injuriously affected by it."

It will be recollected that my samples for trial are taken from the muzzle of the cannon. In the present instance, it was, therefore, from this identical portion of the gun, reported by the inspector to have been of *bad iron*, that I had (in perfect ignorance of this fact) taken out my specimen at least four years afterwards, and had, upon the application of the tests, pronounced an opinion exactly similar to his own.

The foregoing needs no comment; and, taken in connection with the other facts reported, must be regarded as the strongest proof in confirmation of the utility, as well the precision, of this method of ascertaining the quality of gun metal.

4th. During the inspection of some Navy 32 pounders, in 1845, at the

South Boston Foundry, two of them were rejected by the Inspector on account of a few cavities or blow-holes on the surface, arising from a defect in the casting. The others stood the proof, and were received. The founder was confident in the superiority of his guns, and knew that the metal of which they were made was of the same quality with those that had sustained the proof; and as he had to break them up before he could make any further use of the iron, he was determined, in so doing, to make a practical test of their strength. Accordingly, they were submitted to the following very high proof to extremity, and sustained the amount of firing noted in the following table:

Proof to extremity of a 32 pounder Navy Gun, at South Boston Foundry, in 1845.

No. of rounds.	CHARGES.			REMARKS.
	Powder.	Ball.	Wad.	
4	With 7, 8, 9, and 10 pounds, successively	1	1	
4	With 7, 8, 9, and 10 pounds, successively	2	1	
6	With 9 pounds	3 & 4	1	3 rounds with 3 balls, and 3 with 4 balls.
4	With 10 pounds	2 & 4	1	1 round with 2 balls, and 3 with 4 balls.
5	With 11 pounds	2 & 3	1	3 rounds with 2 balls, and 2 with 3 balls.
5	With 12 pounds	2	1	
2	With 13 pounds	2	1	
2	With 15 pounds	2	1	
15	With 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, and 22 pounds	6	1	
1	With 23 pounds	7	1	This charge filled the bore to within 6 inches of the muzzle.
1	With 24 pounds	8	1	This charge filled the bore to within $\frac{1}{2}$ inch of the muzzle.
1	With 25 pounds	7	1	Filled the bore.
51	Rounds, and burst at the last fire of this proof.			

From the fragments of this gun samples were obtained, and, on being tested by the instruments, gave, to a density of 7.23, the extraordinary high tensile strength of 32,000 pounds per square inch, with a character of fracture corresponding to the superior quality of the metal.

5th. A 32 pounder gun was imported from England, in the year 1845, as well for its model as for its supposed goodness of quality. It was sub-

jected to the ordinary foundry proof before being used, but unexpectedly burst at the first fire. Samples of this gun were subsequently tested by the machines, and afforded the following values, namely: a specific gravity of 7.04, and a tensile strength of 18,145 pounds, per square inch. The character of fracture was strikingly correspondent to the quality of the gun.

6th. While at West Point, during the summer of last year, I took a sample for trial from an old English 24 pounder, a trophy of the last war, which had been used by the Cadets in target practice for upwards of fifteen years, and had recently been laid aside from the wearing out of the vent, and the fact of its having already done its duty. It is fair to presume that it has sustained upwards of one thousand rounds, at least, while in use at the Military Academy. This old gun was well known to the Service; and its superior quality was subsequently verified and confirmed by my trials upon the sample, which afforded the high rate, of a tenacity equal to 28,067 pounds per square inch, and a density of 7.205; values which, according to my classification, would have placed it high in the First Class of guns.

2. Facts, illustrating the importance of the Revised Regulations of the Ordnance Department for the Fabrication of Cannon, and the great improvement manifested in the quality of the guns cast under the new system:—

In my previous report it was stated, that since the Ordnance Department had established the present regulations for the government of foundries, and had required the personal attendance of its officers during the fabrication of the cannon contracted for, a marked uniformity was found to prevail in the character of the guns furnished, not only from one foundry, but also among those from different foundries, and throughout the entire period since 1841; while, on the contrary, under the former system of casting, the greatest discrepancies are shown to have existed in the quality of the guns, of the same foundry, and even of the same date of fabrication.

In order that this fact might be more clearly exhibited, I have drawn up the following table, wherein I have classified 589 cannon, from one foundry, into periods, the divisions being marked by the changes observed in the quality of the metal, and the striking relation of those changes to the periods or dates within which the guns were cast.

*Summary of the Classification of 589 Guns, cast at the West Point Foundry,
from 1826 to 1845.*

FIRST PERIOD.		<i>Taking the 2d. and 3d. classes as one.</i>	
From 1826 to 1834 (inclusive), during which 327 cannon were cast, consisting of 32 and 24 pounders.	1st. class	68.50 per cent.	1st. class 68.50 pr. ct.
	2d. class	30.28 "	2d. and 3d. class. 31.50 "
	3d. class	1.22 "	
		<u>100.00</u>	<u>100.00</u>
SECOND PERIOD.			
From 1835 to 1839 (inclusive), when 174 cannon were cast, viz: 8 inch sea coast howitzers, 42, 32, and 24 pounders.	1st. class	4.02 per cent.	1st. class 4.02 pr. ct.
	2d. class	47.70 "	2d. and 3d. class. 95.98 "
	3d. class	48.28 "	
		<u>100.00</u>	<u>100.00</u>
THIRD PERIOD.			
From 1841 to 1845 (inclusive), there being 88 cannon cast, comprising 10 and 8 inch howitzers, 8 inch Columbiads, 42 and 32 pounders.	1st. class	100.00 per cent.	1st. class 100.00 pr. ct.
	2d. class	0.00 "	2d. and 3d. class. 0.00 "
	3d. class	0.00 "	
		<u>100.00</u>	<u>100.00</u>

This table contains, in a summary form, the substance of the foregoing remarks. The great difference of the percentage, for the 2d. and 3d. periods, is strikingly apparent. The system commenced with, appears tolerably good, until the great change is observed subsequent to 1834: from this time, and up to 1840, including the entire period marked 2d. in the table, a very great deficiency in the quality of the gun exists; and for the probable cause of this depreciation, we may look to the introduction of the hot-blast iron. A very striking improvement, however, is evident among the cannon cast under the revised regulations since 1840, which condemned the hot-blast iron, and required, among other restrictions, the personal supervision of Ordnance Officers during the fabrication of the guns. Since that period not a single bad gun has been passed into the service, and the great uniformity in the character, and quality of the metal, affords evidence of a correct and systematic mode of treatment.

GENERAL REMARKS AND CONCLUSIONS.

The following table shows the relation between the strength and density of the metal, and, character of fractures accompanying the different qualities.

Comparative Relation of the Tenacity to the Density of Gun Metal, together with the Characteristic Fracture accompanying the different Qualities thereof.

1ST. TEN CASES AFFORDING THE HIGHEST VALUES OF STRENGTH AND DENSITY, AS EXTRACTED FROM THE RECORDS OF MY EXAMINATION OF A CONTRACT FOR 19, 32 POUNDERS, CAST AT WEST POINT FOUNDRY IN 1841—EVERY GUN OF THE CONTRACT HAVING BEEN RATED TO THE FIRST CLASS ON TRIAL.

Description.	Tensile strength per square inch.	Specific gravity.	Character of fracture.
	Pounds.		
32 pounder, No. 1	28208	7.21	<i>Color.</i> —Light, soft gray, passing into a mottle. <i>Structure.</i> —Close and compact, under a fine and uniform crystalline arrangement. <i>Fracture.</i> —Close and even, not hackly. <i>Hardness.</i> —Of medium resistance to the file, and in the lathe. <i>Aspect of turned surface.</i> —Smooth and even, with few and small cavities.
" No. 2	28349	7.20	
" No. 3	28631	7.22	
" No. 6	29478	7.22	
" No. 8	29619	7.21	
" No. 9	28490	7.20	
" No. 10	31734	7.24	
" No. 11	31734	7.21	
" No. 15	27926	7.21	
" No. 17	28208	7.22	
Mean	29236	7.21	

2D. TEN CASES AFFORDING THE LOWEST VALUES OF STRENGTH AND DENSITY, AS EXTRACTED FROM THE RECORDS OF MY EXAMINATION OF 30, 32 POUNDERS, CAST UNDER THE SAME CONTRACT AT WEST POINT FOUNDRY IN 1839—EVERY GUN OF THE 30 HAVING BEEN REPORTED BY ME AS OF *bad, or doubtful, quality.*

Description.	Tensile strength per square inch.	Specific gravity.	Character of fracture.
	Pounds.		
32 pounder, No. 311	18617	7.08	<i>Color.</i> —Dark gray; sometimes of a dull, non-metallic aspect; at other times, of a brilliant lustre, varying with the size and aggregation of its crystals. <i>Structure.</i> —Open and granular, with large stellated crystals irregularly grouped. <i>Fracture.</i> —Rough, uneven and hackly. <i>Hardness.</i> —Of soft and slight resistance to the file, drill, and in the lathe. <i>Aspect of turned surface.</i> —Rough and uneven, with large stellated and plumose cavities, apparently the beds of the crystals removed by the action of the turning tool.
" No. 312	19887	7.08	
" No. 316	19323	7.05	
" No. 318	19887	7.07	
" No. 321	19887	7.04	
" No. 324	19323	7.09	
" No. 325	19464	7.03	
" No. 329	19887	7.04	
" No. 332	19323	7.03	
" No. 335	19323	7.03	
Mean	19492	7.05	

From this table it appears, that not only is there a striking relation between the strength and density of the metal in the same gun, but also, that the character of fracture corresponds to the difference of quality. We also perceive that in guns from the same foundry, and constituting a part of two separate contracts, there exists a difference of nearly 10,000 pounds per square inch, in tenacity, and 0.15, nearly, in the density of the metal. Those in the latter part of the table are some of the guns reported as hot-blast; and those comprised in the former part were cast the next after them, at the same foundry, though not until the system had been revised, and the officers of the Ordnance Department charged with superintending their fabrication.

In order to show how far the durability of the gun is dependent upon the tenacity and density of the metal, I have drawn up the following table:—

Comparative Endurance of certain Cannon subjected to High and Extreme Proof, with the Value of the Tenacity of the Metal, of each, subjoined.

Description of gun.	Specific gravity.	Tensile strength.	Endurance.	Rank of tenacity.	Rank of endurance.
		Pounds.			
6 pounder No. 7, cast at the South Boston Foundry in 1844.	7.213	32231	16 rounds, with 2 pounds of powder, and an additional ball at every round; making the 16th charge, 2 pounds of powder and 16 balls. 4 rounds, with 2½ pounds of powder, and successively, 13, 14, 15, and 16 balls at a charge. 16 rounds, with 3 pounds of powder and 16 balls each; and, finally, 2 rounds, with 6 pounds of powder and 7 balls, and could not be burst. The service charge being 1½ pound of powder and 1 ball, only. 51 rounds, with increasing charges from 7 pounds of powder, 1 ball, and 1 wad, up to 25 pounds, 7 balls, and 1 wad; and burst at the last fire, when filled to the muzzle. The service charge being 4 pounds of powder, 1 ball, and 1 wad.	1	1
Navy 32 pounder, cast at the South Boston Foundry.	7.23	32000	1000 rounds and upwards, with service charges, at the United States Military Academy, besides what it might have previously sustained before its capture. The gun has been withdrawn from battery (the vent being worn), and replaced by one of the new model.	2	2
24 pounder English gun, captured from the British during the late war.	7.205	28067	51 rounds, service charges; burst during target practice at Fort Monroe, Va., at the 51st round.	3	3
18 pounder siege gun, cast at the West Point Foundry in 1839, of hot blast iron.	7.01	22900	1 round, with the proof charge of — powder and ball; and burst at the very first fire.	4	4
English 32 pounder, Navy gun, imported in 1844.	7.04	18145	20 rounds, with the service charge. 16 rounds, double shot; and burst at the last fire.	5	5
32 pounder No. 61, cast at the Bellona Foundry in 184—.	7.03	16313		6	6

We will readily perceive from this table, the relation of tenacity and density of the metal to the durability of the gun. It will be recollected that I have, in my classification, assumed 25,000 pounds per square inch, as the lowest limit of strength, for guns of the 1st. class; and hence, the three highest guns on the list would have come under this head, while the remainder would have been rated to the 3d. class, and, very properly, recommended for condemnation.

GENERAL REMARKS AND CONCLUSIONS.

1st.—*Samples for Trial.*

In the first stage of the experiments, samples for trial were taken from the trunnion, of the guns. The results therefrom could not be depended on, as the rapid cooling and chilling of this comparatively small portion of the metal, together with the frequent occurrence of sand or scoria, which during the operation of casting becomes inclosed therein, very materially affected the strength and density of the metal. The same objections, in part, were found with specimens taken from the knob of the cascable. The sample, most accessible in any position of the gun, and, most to be relied on for accurate results, was that taken from the muzzle; because, the metal cooling there under the pressure of the sinking head, and in a larger and more proportionate mass, would approximate more nearly to the body of the gun; and, further, that in this part it would be contiguous to the sample plate, taken, by order of the Department, from the cannon recently cast, and deposited as a specimen of the gun in the Model Office at Washington.

Repeated experiments have proved that the removal of this sample from the face of the muzzle occasions no injury to the gun.

2d.—*Manner of refilling the Cavity thus left.*

To avoid disfiguring the surface of the gun, the perforations left by abstracting the sample are compactly filled with a moistened composition of sal-ammoniac and fine iron turnings. Rapid chemical action immediately ensues upon adding water to this mixture; decomposition of the sal-ammoniac and water takes place, and the resulting compound, of the chloride and oxide of iron, forms a cohesive mass, which cements itself firmly to the sides of the cavity. This composition indurates in the course of a few hours, and in that state, sustains both the effects of weather and the heaviest shocks of firing, unimpaired.

3d.—*Specific Gravity of Gun Metal.*

The specific gravity of gun metal has some relation to its tenacity and hardness. Its value varies in different cannon between the limits of 6.9 and 7.4. From 7.18 to 7.25, or even within the wider range, from 7.16 to 7.3, is

considered a proper value for a good gun, when accompanied with other necessary conditions; when it falls below the former limit (7.16), the metal is too soft, and is, generally, deficient in tenacity, and when it exceeds the higher limit, it becomes too hard and brittle.

This remark, of course, applies to such guns as have been cast under the former system, for it is possible with proper treatment during the fusion and subsequent cooling of the metal, to attain even a higher degree of density without impairing its tenacity. The value, however, of the specific gravity is so dependent on certain conditions attending the casting, that, by itself, it cannot be regarded as a sure index of the quality of the iron; although in connection with other tests it may be highly useful.

4th.—*Tenacity of Gun Metal.*

The tensile strength appears to be, in most instances, the surest test of the quality of the metal. When a gun exhibits this property, in connection with a corresponding density, and the character of fracture that seems in general attendant thereon, the inference is strongly in favor of its strength and durability.

5th.—*Character of Fracture.*

To an experienced eye, one of the best indications of the quality of the metal is afforded by its character of fracture, and in the absence of other tests, it may be of much use. The peculiarity of the *color of structure*, and the form and size of the crystals, all of which seem to vary correspondingly with the other properties, serve to point out the quality of the iron. An examination of the turned surface of a sample, when the fracture cannot be had, is also useful, as it affords *prima facie* evidence of the structure of the iron; it having been observed that when the surface is pitted with large and stellated, or plumose cavities (apparently the beds of the crystals removed by the action of the turning tool), the metal is of a loose and open structure, while under the same circumstances, a close grained and compact iron has generally its turned surface smooth and even, and is either without these cavities, or else with but few, very small and finely marked.

For a general description of the character of fracture of different qualities of gun metal, I refer to Table III, of this report.

6th.—*Exceptions to the General Relation of Strength and Density.*

Although, in general, a very close relation seems to exist between the tenacity and density of cast iron, yet this, it is found, does not always occur. There are cases where a medium tensile strength is observed to accompany a high degree of density, and the reverse, where a low density is found in connection with a good value of strength; in the latter case, however, the value of the tenacity is never very high. Such exceptions, however, instead of throwing objections in the way, serve only to prove the rule, by giving rise to further investigations; and I have endeavored, therefore, to account for them in the following manner:

When a case of the first kind occurs, I have noticed that the metal has generally a white aspect, either a very high mottle, with the white of a silvery hue, or of a uniform, dull, and chalk-like appearance; a circumstance which may be attributed either to its having been too frequently remelted, or to its too long continuance in the furnace, or to the fact of its having been suddenly cooled from a state of fusion.

In the second case, where we find the low density belonging to a good, though not a very high degree of tenacity, it is uniformly observed that the surface of fracture presents a dark and carbonaceous appearance, yet with a very closely aggregated crystallization. I have, therefore, concluded that its excess of carbon rendered its density necessarily low, while, by reason of its close structure, and the increased number of its fibres or crystals, its tensile strength has been greatly augmented. For the cause of this peculiarity, we may look to the quantity of its carbon, as due either to the nature of the fuel, or to a deficiency of oxygen in the blast during the course of its treatment in the furnace.

Where instances, like either of the foregoing, have been found, I have uniformly classed the gun, to which they belong, as *doubtful*. For if the iron is deficient in tenacity, it is evident that the gun cannot possess the requisite strength; and when the density is low, the metal, I fear, would be too soft to resist the effects of the ball in firing. In the latter instance, I would suggest that the application of a crushing force be made to the sample. An insufficient resistance to such a force would, I think, indicate its inability to withstand the action of the ball, although the metal might otherwise possess a good degree of tenacity.

7th.—*Resistance to a Crushing Force.*

In cases like the foregoing, when the usual relation does not exist between the density and tensile strength, I have thought that the power of the metal to resist a crushing force might be, advantageously, tested. I have for this purpose made such an arrangement to the breaking machine, that the specimen (which is to be half of the sample left after taking the value of its tensile strength) shall be properly retained in its position, while the crushing force is applied in the direction of the axis. The ratio of this force to the tenacity and density of the metal, and then again, its relation to the durability of the gun, might afford additional and useful data. The few samples that I have as yet tried, in this manner, are sufficient to show, that this additional arrangement to the machine answers fully the purpose for which it was intended.

8th.—*Proof to Extremity by Gunpowder.*

Under the 4th head in the programme of experiments, it was proposed to submit some of the guns to extreme proof under gunpowder and hydrostatic pressure.

The results of the proof by gunpowder, as far as made, have satisfactorily verified those afforded by the other tests.

9th.—*Proof by Hydrostatic Pressure.*

This test has been satisfactorily employed in cases only of extreme proof.

Under a moderate degree of pressure, say 3, to 4,000 pounds per square inch, this test might be useful in detecting flaws or cavities in the metal. It would not, however, answer with guns cast before the Revised Regulations, as the hardened crust of chilled iron on their exterior surfaces, arising from the coldness of the mould, would prevent the penetration of the water, and thus afford no indication of the existence of imperfections in the body of the metal. I have seen a case where the force of the water, collected under this crust through a fissure in the mass of the metal beneath, has raised it in the form of a spherical segment, of an inch in diameter above the surface of the gun, and not until broken through by an increased pressure was there a leak of any kind to indicate the flaw. With the guns of recent fabrication, however, which, besides being cast with more care, have their exterior surfaces completely turned off under the lathe, this objection would not exist. To

such, a moderate pressure might, if thought necessary, be applied, and the soundness of the metal ascertained, although from my own experiments, I would hesitate to reject a gun where the leaks were only found in front of the trunnions.

One of the most interesting results I derived from the extreme proof by this test, was to measure the value of the cohesive force of the metal by the given values, of the pressure per square inch on the fluid, the thickness of the metal, and the radius of the cylinder or bore.

In order to do this, I applied the formula found in Barlow (Strength of Materials), which gives, in terms of the above values, the expression for the greatest resistance to which a cylinder can be safely subjected under such a force, and by equating it with the value of the strain due to the given pressure and radius, the resulting value of the cohesive strength was found, in the case of two different guns, to agree very strikingly with that of the absolute strength of the same metal, as obtained from direct experiments with the breaking machine.

The present annual report embraces a general view of the most important results derived from the late re-examination of the cannon at the several Forts, Arsenals, and Depots, throughout the country, and, with its conclusions, is herewith respectfully submitted for consideration.

L. A. B. WALBACH,

First Lieutenant of Ordnance.

TO COLONEL OF ORDNANCE.

REPORT

ON THE

EXTREME PROOF OF 1ST., 2ND., AND 3RD. CLASS GUNS, AND
8 INCH AND 10 INCH HOWITZERS,

BY

CONTINUOUS FIRING WITH SERVICE CHARGES.

FORT MONROE ARSENAL.

1853.

REPORT

EXTREME TROOP OF 102 GUN, AND THE GLASS GUN, AND

2 INCH AND 10 INCH HOWITZER.

JOINT MONITOR REVIEW

1882.

REPORT

ON THE

FIRING OF TEST GUNS (1st. 2d. AND 3d. CLASSES) AT FORT MONROE ARSENAL, VA., BEGAN JULY 5, 1852, AND COMPLETED MAY 9, 1853, BY BREVET MAJOR GEO. D. RAMSAY, ASSISTED BY 1st. LIEUT. G. GORGAS, ORDNANCE, PURSUANT TO DIRECTIONS FROM THE CHIEF OF ORDNANCE.

WITH the instructions from the Department was transmitted the following extract from a Report of the Ordnance Board of January 30th, 1852.—

“10th. The practical test, by firing with service charges, of the correctness, in classifying the iron guns, &c. &c.

“Referring to the recommendation of the Board at its session in March, 1849, the following programme is now submitted for the trial of the *classed* guns of the several foundries, to be collected at Fort Monroe, and to be fired as follows, viz: *Powder charges, one-fourth the weight of the ball respectively, with one shot, and one junk wad over the ball.* With such charges, the firing to be continued to 500 rounds, unless the gun previously burst. After 500 rounds, as above, *the charge to be increased by adding one ball every discharge, until the bore is filled.*

“Should the gun withstand all this, *increase the powder charge to one-half the weight of the ball respectively, and fill the bore with shot.*

“Whenever a gun bursts, specimens of the metal from these several points are to be preserved, viz: from the breech, near the trunnions, and the chase.

* * * * * “The powder should be of the same strength, as nearly as practicable, and all from the same manufactory.”

Extract of a Letter from the Colonel of Ordnance, dated August 16, 1852:—

* * * * * “In the test firing, you may use a grommet, or hay wad, to keep the ball in place; and one of the 3d. Class guns of each Calibre may be fired up to 800 rounds of service charges, before using the increasing charges.”

The Test Guns designated, the firing of which is completed, were—

6, 24 pdrs.	West Point Foundry, 2 of each Class.
6, 24 “	Bellona “ “ “ “
6, 32 “	West Point “ “ “ “
6, 32 “	Bellona “ “ “ “
1, 8 in. Columbiad	South Boston “
1, 8 “ “	West Point “
1, 10 “ “	South Boston “
1, 10 “ “	West Point “

} Cast since the
Classification.

The 24 and 32 pdr. guns were fired in sets of 3, by calibres, as follows: one of the 1st., one of the 2d., and one of the 3d. Class, of the same Foundry, in each set. The guns were suspended, by iron slings, in frames (as in the experiments at Alleghany Arsenal); and a suitable cover-proof, or shelter for the men, was provided, and a butt to receive the balls. The 8 and 10 inch Columbiads were fired in sets of 2, each calibre by itself.

In firing one gun of each Class at the same time, it is supposed the comparative value of the test has been rendered more satisfactory—the Classes represented in the guns being thus treated in precisely the same manner. Every gun of the set was fired, by this disposition, with the same balls, with powder out of the same barrel, in the same temperature and condition of the atmosphere—in short, under an identity of all the circumstances likely to affect the endurance.

The proof ranges of the powder varied from 260 to 312 yards, and it was from different manufactories. The firing of a gun from each Class at the same time, it was supposed, rendered the precaution suggested by the Board, in a measure unnecessary.

A straw grommet, weighing twelve to the pound (being simply a wisp of straw wound with marline), was used to keep the ball in place, in the firing with service charges. The guns in the slings had a depression of two to

three degrees. When the limit of service charges was attained, the guns were taken down from the slings, and removed to a safe distance for firing with the increased charges.

The 24 pdrs. admitted of 16 increased charges, viz: the service charge of powder (6 lbs.), with 2, 3, 4, 5, &c., balls up to 16, and one double charge of powder with 16 balls, as prescribed in the instructions.

The 32 pdrs. admitted of fifteen increased charges, viz.: the service charge of powder (8 lbs.), with 2, 3, 4, 5, &c., balls up to 15, and one charge of double weight of powder (16 lbs.) and 15 balls. The 8 inch Columbiads admitted of 11 increased charges, viz: the service charge of powder 10 lbs. with 2, 3, 4, 5, &c., solid balls up to 11, and one charge of 20 lbs. of powder, and 11 solid balls. The 10 inch Columbiad admitted of 9 increased charges, viz: 18 lbs. of powder, with 2, 3, 4, 5, &c. solid balls up to 9, and one charge of 36 lbs. of powder, and 9 solid balls. The maximum charge, in each case, filled the gun. A wad was, in all cases, put on top, in the increased charges, and, in some few rounds, intermediate wads were used, for the convenience of loading.

At stated intervals, the bore was measured with the star gauge, and the interior and exterior enlargements of the vent ascertained.

The results of these measurements are condensed in annexed tables, and a sheet exhibiting the interior of the vents of several guns, is appended.

The enlargements of the bore have in no case been material, and no gun, remaining whole, exhibits any injury by the firing it has sustained, of a character to interfere with its use.

Not more than 15 per cent. of the 24 and 32 pdr. balls were destroyed in firing the service charges.

Of the Columbiad balls, but five or six were broken in all.

The small gauge was occasionally applied to balls which were frequently refired.

The 10 inch Columbiads were, in part, fired (through motives of economy) with shells unfit for issue, brought up to the proper weight with zinc; the specific gravity of which equals that of cast iron. Shells so filled would endure an average of five fires into the butt.

Much of the labor and most of the fatigue of the firing, arose from the vibration of the guns in the slings. A party of eight men were required to stop a 24 pdr. gun, and a proportionately greater force for the other calibres.

It was found that all this part of the labor could be avoided, by the following arrangement:—

A drag, made of blocks strongly bolted together, hollowed and loaded with lead, was attached by heavy ropes to the neck and cascable of the gun.

The friction of this drag, sliding on a firm platform furnished with guides, effectually checked the vibration, so that the gun was ready for reloading by the time the men could reach it from the cover-proof. Instead of eight, two men sufficed for each gun, and the firing was performed with much greater rapidity. These drags weighed 900 to 1,000 pounds. The ordinary number of rounds fired per day, varied from 80 to 130 per gun, though the average was considerably less than these figures owing to interruptions from the weather and other causes. The greatest number of rounds fired on any day, was 406, with three 32 pdrs.

The 8 and 10 inch Columbiads were fired at the rate of from 35 to 65 rounds, each, per day.

The guns were washed while warm in a few instances only, which are noted in the proper place.

The washing was generally done in the morning before the commencement of firing.

Frequent examinations of the bores were made, with a view of detecting interior cracks, such as are supposed to have existed about the bottom of the bore of the guns fired at Pittsburg; none such were discovered in these guns. The same watchfulness has been exercised at the neighboring Naval battery, thus far, with the same want of success.

No remarks on the appearance of the iron of the broken guns are deemed in place in this report; that portion of the recommendation of the Board referring to the taking of specimens, in order to ascertain the quality of the iron at certain points of the gun, having been entrusted to another Officer.

SUMMARY OF THE RESULTS.

Endurance.

Of the 1st. Class guns (not Columbiads), but one burst with service charges.

Of the 2d. Class, three burst with service charges.

Of the 3d. Class, five “ “ “ “

The worst guns appear in the 3d. Class, five of which burst between the 52d. and 208th. service round. The least number of rounds borne by a 2d. Class gun, was 277; another burst at 318, and another at 409.

The quantity of powder and shot thrown from each Class, is shown in a statement (C) attached.

Tensile Strength.

The tensile strength of the six guns which endured the prescribed firings, varies from 24,500 to 31,700. The anomalous endurance of three of the 3d. Class guns (one of which withstood all the tests) may, perhaps, be elucidated by the specimens hereafter to be taken and tested.

The bursting of the 10 inch Columbiad, at 94 rounds, seems to point to the conclusion, that high tensile strength does not infer security from bursting.

It will be observed, that all the guns of tensile strength between 26,000 and 32,000, have, with one exception, endured the 500 rounds service firing; and that exception is not, as will be seen by reference to the abstract of the firings, of a marked character. On the whole, the irregularities appear to be less, in the tensile strength comprehended in these limits, than in those above or below them.

Fracture, and Direction of Fragments.

Of the nineteen guns burst, two, only, have not split through the vent. Of these latter, one parted nearly in the plane of the trunnions, the other, in a plane making an angle of about 30° with the vertical and passing through the axis.

When broken with the service charge, the fracture has been, with few exceptions, close to the trunnions; with heavy charges, the guns broke nearer to the muzzle.

The direction of those fragments projected to any considerable distance, has been very uniform. It has, in all cases, been to the rear of the trunnions, and within the angle of 45° from the line of the trunnions. No piece has been thrown to the front of that line, except, perhaps, a trunnion from the first gun burst, which fell at the distance of a few feet only. The knob of the cascable has occasionally been thrown to the rear, and in one case, the entire breech went 10 feet back.

The positions of safety would, therefore, appear to be: firstly, in front of the trunnions, and secondly, to the rear and within the angle of 45° , on either side of the axis of the gun prolonged.

Annexed will be found—

1st. An abstract (A) of the firings of all the guns, in the order suspended.

2d. A table (B), showing in juxtaposition, the order of "tensile strength" and of "endurance," of the 24 and 32 pdrs., and the service, and increased rounds, sustained by each.

3d. A statement (C) of the quantity of powder, and shot, consumed in, and thrown from each Class, and from the Columbiads.

4th. A table (D) of the enlargements of the bores of various guns.

5th. A table (E) of the enlargements of the exterior of the vents.

6th. A table (F) showing the "tensile strength" and "specific gravity" of specimens taken from the burst guns.

7th. A sheet exhibiting the interior enlargements of the vents.

Attention is called to the variation in the texture of the successive laminae of metal, encountered in boring a new vent in the 10 inch Columbiad, noted in its proper place. (See No. 2, of 10th. Set.) As similar observations were made, in a like process, at Pittsburg last year, the facts seem to assume significance, in connection with the specimens to be taken at the different points indicated in the recommendations of the Board.

A specimen taken from the depth of two inches from the surface, could not safely be assumed as an index of the quality of the metal of the mass in that vicinity, as the next succeeding inch might have a character essentially different.

The only method of counteracting any errors arising from this source, would be, to take as many specimens, in each section perpendicular to the gun's axis, as would insure a fair average.

It would be injustice to Lieut. Gorgas, of the Ordnance, not to mention in terms of commendation, his connection with the experiments set forth in this report. His ability and industry have greatly contributed to the results herewith presented to you.

Respectfully submitted,

GEO. D. RAMSAY,

B't-Major, commanding.

FORT MONROE ARSENAL, VA.,

May 31, 1853.

NOTE.—Since the completion of the foregoing report, 32 pdr. gun, No. 186, has been again fired, under permission from the Col. of Ordnance, in the following manner, at the suggestion of Lieut. Gorgas.

A hole was drilled into the gun, 1 inch forward of the base-ring and 4 inches from the line of the vent, to a depth of 4 inches, and of a diameter of $1\frac{1}{4}$ inches. The gun was then fired, with double charges of powder, and with the bore full of balls and wads, 11 times, to bursting. At the 6th charge, a longitudinal crack through the vent was distinctly visible. It continued to enlarge, and had attained a length of 5 inches forward, and 2 inches in rear of the vent, before the last fire.

Although the piece burst into more than twelve fragments, it did not split through the large hole; showing, that a piece of sufficient size for all desirable tests, may be taken from the vicinity of the breech without injury to the strength of the gun.

A.

ABSTRACT OF THE FIRINGS.

FIRST SET—24 PDRS. *Suspended July 5, 1852.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
1st. Class gun, No. 1	1827	Bellona	J. B.	28208	7.18	371	{ 15, regularly increased. 6, with 12 lbs. powder and 16 balls. 10, 18 lbs. powder and 10 to 14 balls. 16, regularly increased.
2d. Class gun, No. 7	1827	"	J. B.	22566	7.15	539	
3d. Class gun, No. 173	1838	"	W. M.	19040	7.14	800	

1st. Class.—This gun endured but 371 rounds. The size of the vent, (.275) at the commencement of firing, showed some degree of service. By reference to the table of enlargements of the vents of other guns, it may fairly be presumed to have endured from 125 to 200 rounds in advance, bringing its bursting point to the neighborhood of 500 rounds service charges.

Another circumstance which may have hastened the apparently premature destruction of this gun, was the boring of two holes (one inch deep and three-quarters of an inch in diameter,) in the cross-section through the vent,

and three inches on each side of it, for fastening a lock. (It must be observed, however, that gun No. 7, 2d. Class, was treated in precisely the same manner without visible injury to its endurance.) This gun broke into three principal fragments, through the vent and at the trunnions, as shown in PLATE XXII, Fig. 1. In bursting, a fragment struck one of the neighboring guns, deflecting it, at the moment of its discharge, through an angle of 90°. The ball from it passed over Carroll Hall and fell into Hampton Roads.

2d. Class.—That this gun had also been previously fired, was presumed, from the size of the vent (.25). An error in the count caused it to be carried beyond the prescribed number of service charges, and, from a misconception of the tenor of the Instructions from the Department, it was fired with heavy increased charges beyond the limit therein intended, and since observed.

It bore therefore, 539 service charges; 15 regularly increased; 6, with 12 pounds of powder and 16 balls; and 10, with 18 pounds, and 10 to 14 balls, alternating with junk wads driven in with a sledge hammer. It burst into 8 or 9 pieces, through the vent, and leaving but 3 feet of the chase whole. See Fig. 2, PLATE XXII.

The fragments were thrown to various distances from 3 to 900 feet, and one large piece striking the cover proof, destroyed it. The men had been withdrawn for some fires before.

3d. Class.—This gun was fired up to 800 rounds service charges, pursuant to general instructions referring to that Class. It was then removed for firing with increased charges, and only burst at the last or double charge. Before the last fire a crack was apparent, through the top of the lock-piece and extending a few inches on either side of the vent. Fragments, of several hundred pounds weight, were thrown to the distance of some 500 yards.

SECOND SET—24 PDRS. *Suspended September 24, 1852.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
1st. Class, 24 pdr. No. 40	1828	Bellona	J. B.	29055	7.209	500	14, regularly increased.
2d. Class, 24 pdr. No. 163	1837	"	J. W. R.	23272	7.15	409	
3d. Class, 24 pdr. No. 174	1838	"	W. M.	14104	7.10	500	13, regularly increased.

THE HISTORY OF THE

REIGN OF

CHARLES THE FIRST

BY

JOHN BURNET

OF

THE UNIVERSITY OF OXFORD

IN TWO VOLUMES

LONDON

Printed by J. Streater, at the Sign of the Gun, in St. Dunstons Church-yard, 1679.

THE SECOND VOLUME

OF

THE HISTORY

OF

THE

REIGN

OF

CHARLES

THE

FIRST

BY

JOHN BURNET

Fig. 1.

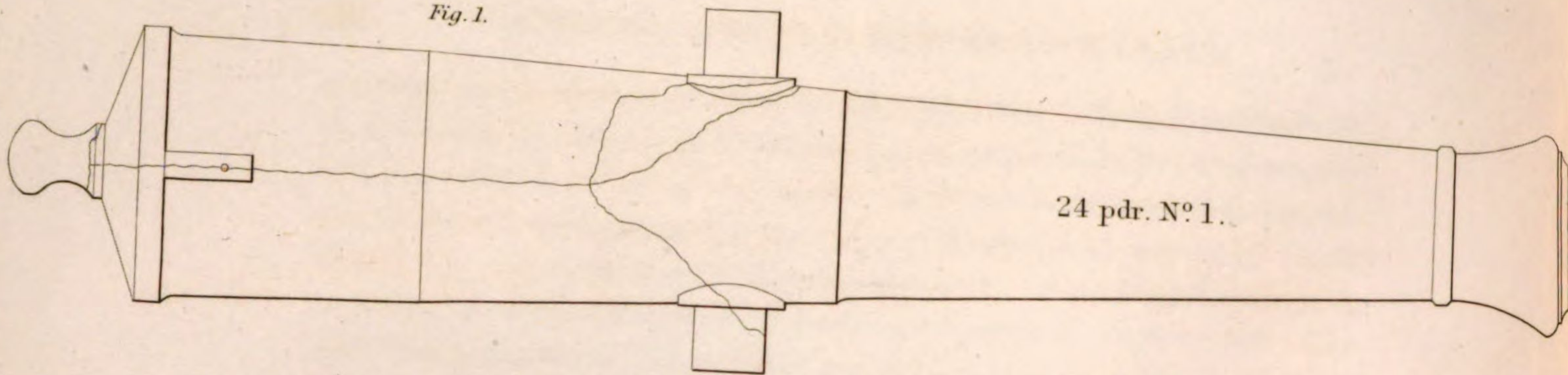


Fig. 2.

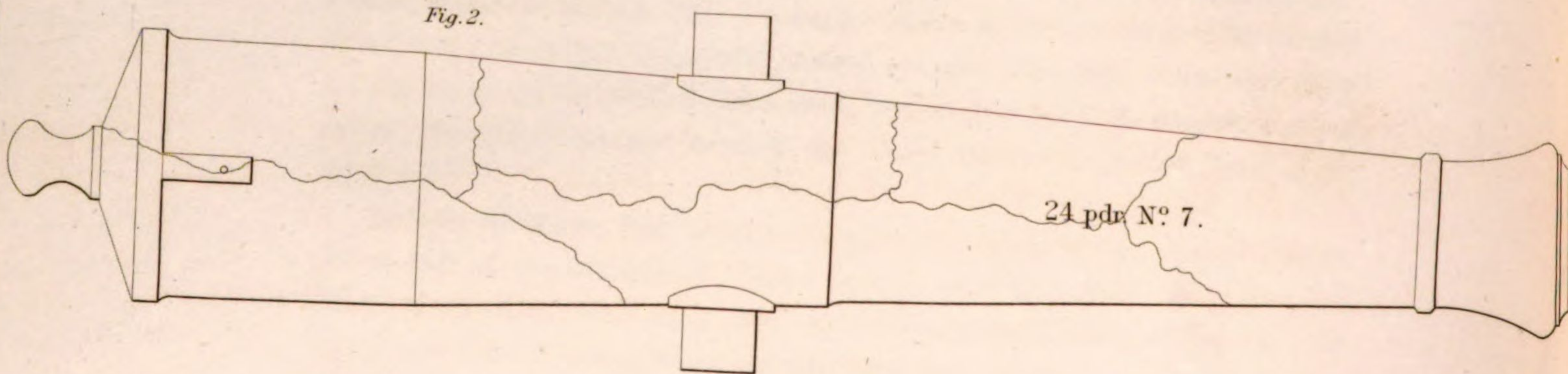


Fig. 3.

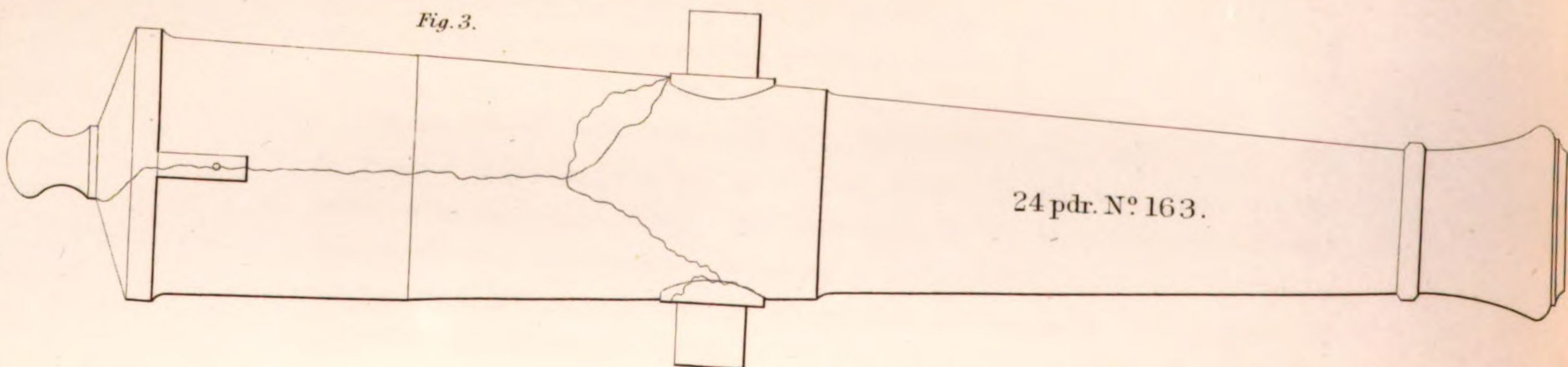
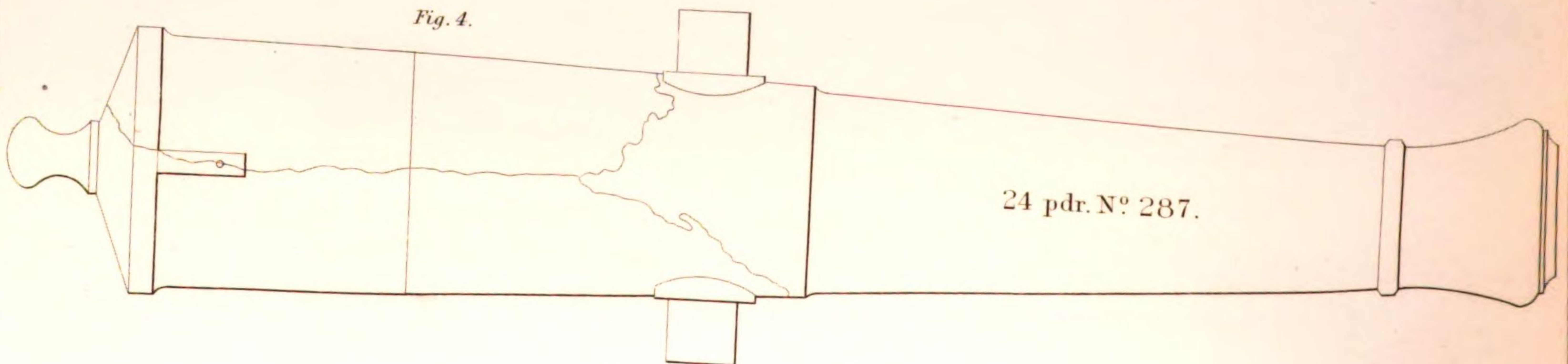


Fig. 4.



Scale $\frac{1}{15}$.

1st. Class.—Broke at the 12th. fire in the morning. Fracture, through the vent, and at the trunnions, leaving one trunnion on the chase. The vent of this gun enlarged more slowly than those of the other two. PLATE XXIII, Fig. 1.

2d. Class.—Broke at the 277th. service charge, at the 42d. fire of the day. The fracture is through the vent, and at the trunnions, leaving one trunnion on the chase. PLATE XXII, Fig. 4.

3d. Class.—Broke at the 148th. service round, at the 12th. fire in the morning. Fracture, through the vent, and at the trunnions, leaving one on the chase. The vent of this gun enlarged more slowly than those of the other two. PLATE XXIII, Fig. 1.

The broken surface of the chase bears the impress of balls, showing that the fracture was complete before all of the balls had left the bore.

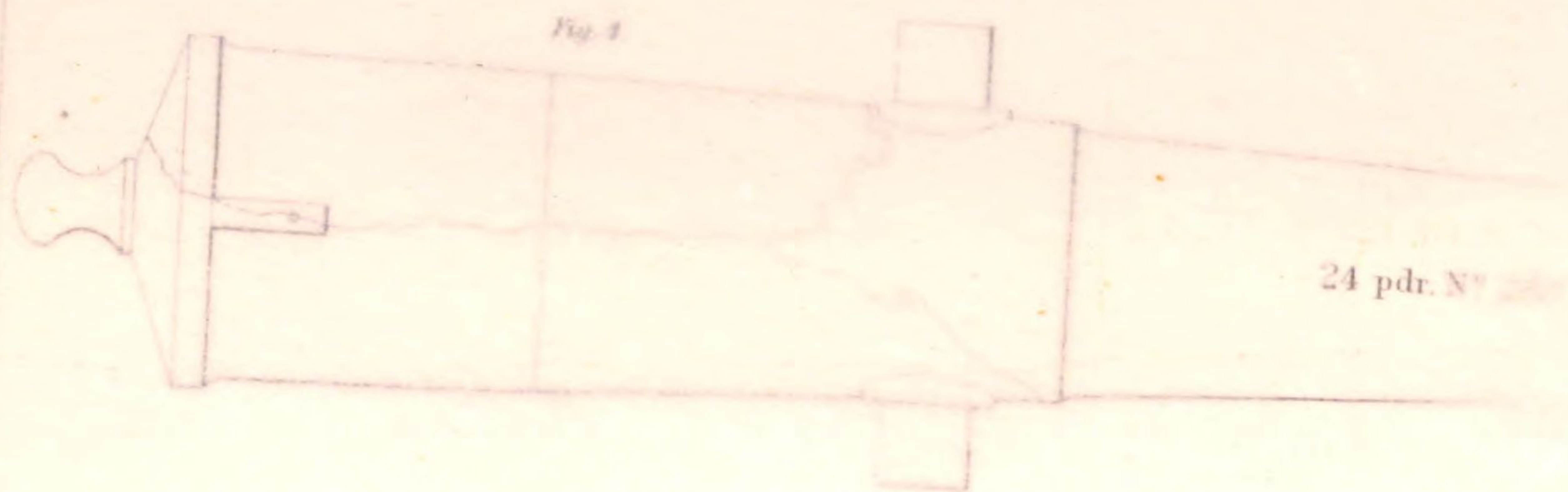
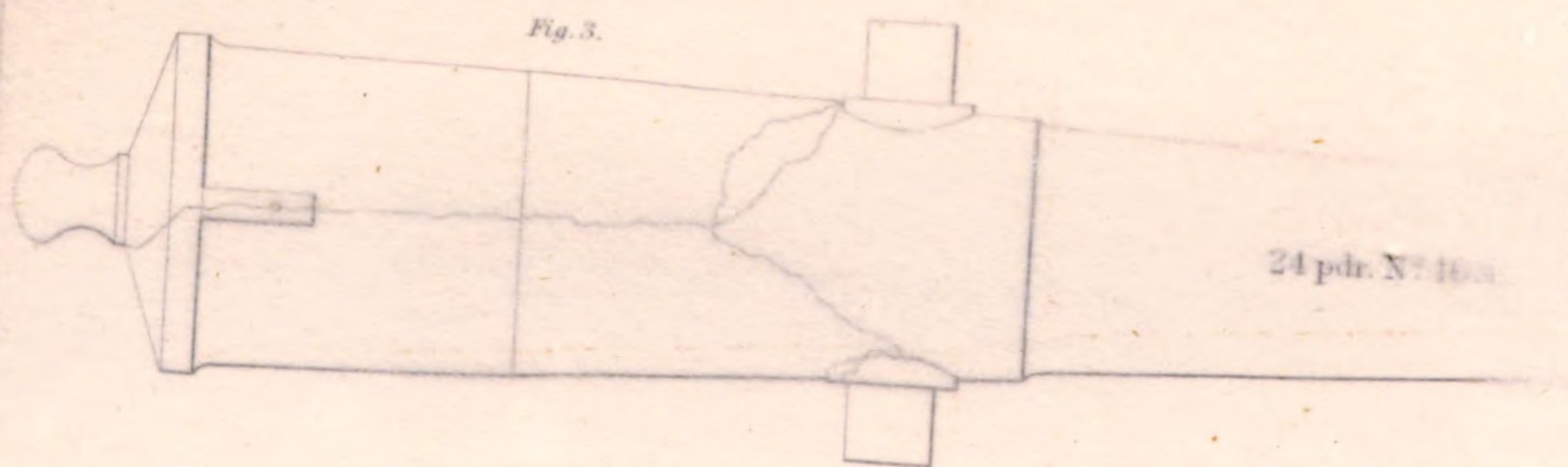
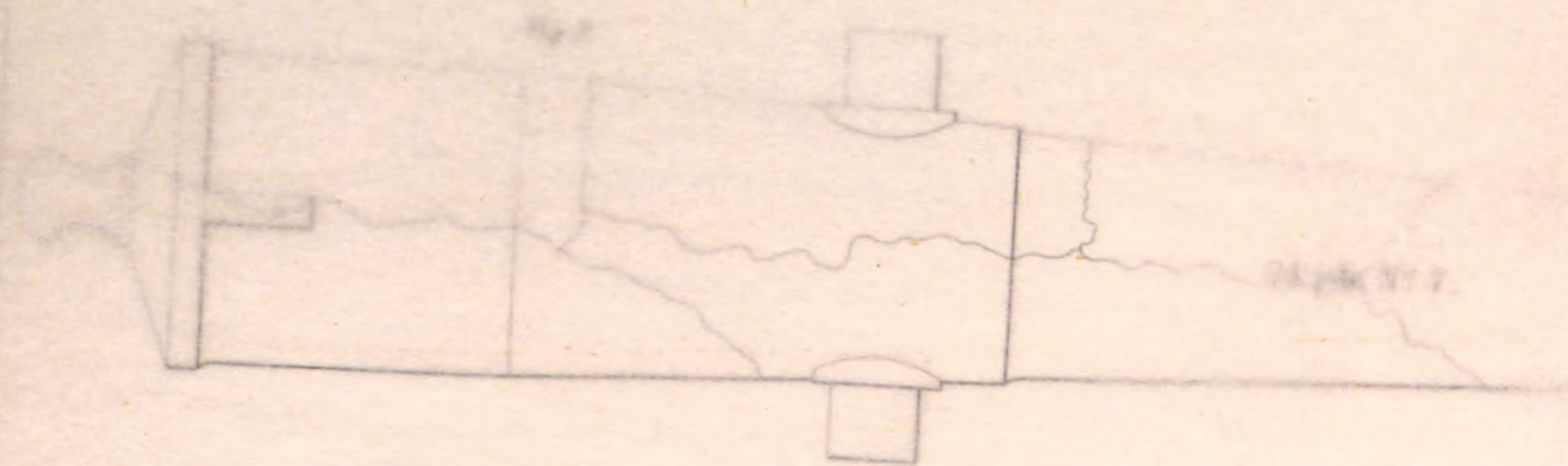
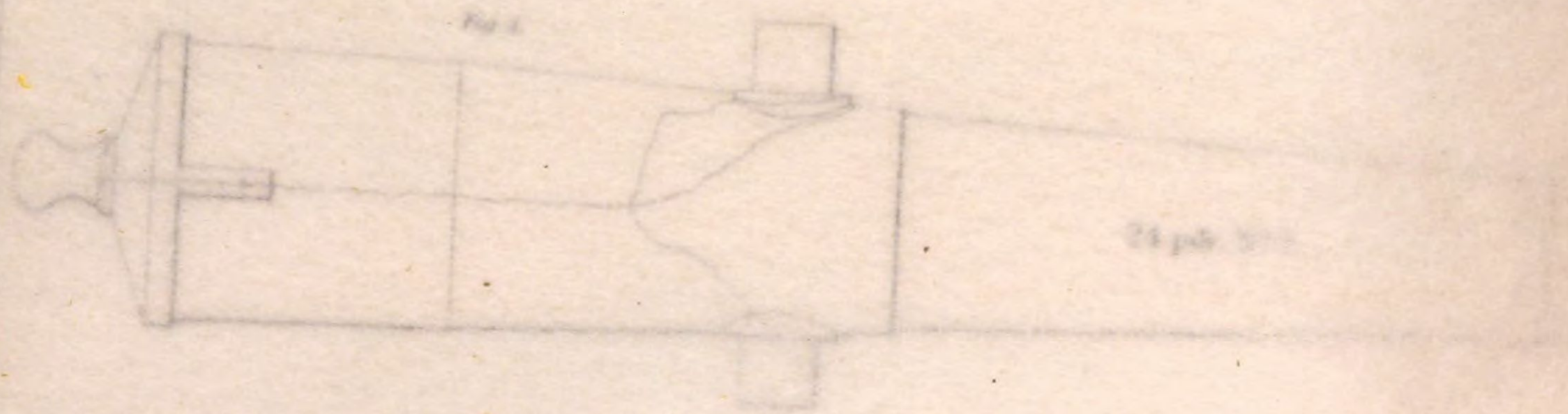
THIRD SET—24 PDRS. Suspended Gun No. 19, 1838

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Service charges.	Service rounds.	Remarks.
1st. Class, 24 pdr. No. 193	1828	West Point	J. B.	28208	7.155	500	16, regularly increased.
2d. Class, 24 pdr. No. 287	1837	"	J. W. R.	23336	7.147	277	
2d. Class, 24 pdr. No. 309	1838	"	J. W. R.	{ 21453 20628 }	{ 6.996 7.08 }	148	

1st. Class.—Sustained 500 service charges, and burst, through the vent, at the 16th. increased charge, with 12 pounds of powder and 16 balls. This gun had a lock attached, for which four holes were drilled near the vent, but not in the cross-section through it. The holes were 1 inch deep by .62 diameter.

2d. Class.—Burst at the 277th. service charge, at the 42d. fire of the day. The fracture is through the vent, and at the trunnions, leaving one trunnion on the chase. PLATE XXII, Fig. 4.

3d. Class.—Broke at the 148th. service round, at the 12th. fire in the morning. Fracture, through the vent, and at the trunnions, leaving one on the chase. The vent of this gun enlarged more slowly than those of the other two. PLATE XXIII, Fig. 1.



Scale 1/2.

1st. Class.—Fired with service charges to 500 rounds, between September 24, and October 15. It was then removed to be fired with increased charges. On the 2d. and 3d. of November, it was so fired, and burst at the 14th. round, viz: with 6 pounds of powder, 15 balls, and one wad—into 5 pieces, breaking from the chase, just in front of the trunnions, and splitting through the vent.

2d. Class.—Broke in the slings, at the 409th. service round, at the second fire in the morning, into three principal fragments, through the vent, and at the trunnions—the left trunnion remaining on the chase. The left half of the breech struck the cartridge magazine, standing about 15° to 20° to the rear of the line of the trunnions, and slightly wounded a man behind it. See PLATE XXII., Fig. 3.

3d. Class.—Sustained 500 service charges, and broke at the 13th. increased charge with 6 pounds and 14 balls—just at the rear of the trunnions, and through the vent.

The broken surface of the chase bears the impress of balls, showing that the fracture was complete before all of the balls had left the bore.

THIRD SET—24 PDRS. *Suspended October 18, 1852.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
1st. Class, 24 pdr. No. 193	1828	West Point	J. B.	28208	7.185	500	16, regularly increased.
2d. Class, 24 pdr. No. 287	1837	"	J. W. R.	23836	7.147	277	
2d. Class, 24 pdr. No. 309	1838	"	J. W. R.	{ 21453 20028 }	{ 6.996 7.08 }	148	

1st. Class.—Sustained 500 service charges, and burst, through the vent, at the 16th. increased charge, with 12 pounds of powder and 16 balls. This gun had a lock attached, for which four holes were drilled near the vent, but not in the cross-section through it. The holes were 1 inch deep by .62 diameter.

2d. Class.—Burst at the 277th. service charge, at the 42d. fire of the day. The fracture is through the vent, and at the trunnions, leaving one trunnion on the chase. PLATE XXII, Fig. 4.

3d. Class.—Broke at the 148th. service round, at the 12th. fire in the morning. Fracture, through the vent, and at the trunnions, leaving one on the chase. The vent of this gun enlarged more slowly than those of the other two. PLATE XXIII, Fig. 1.

FOURTH SET—24 PDRS. *Suspended October 25, 1852.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
1st. Class, 24 pdr. No. 186	1828	West Point	J. B.	28067	7.185	500	16, regularly increased.
2d. Class, 24 pdr. No. 290	1837	"	J. W. R.	23413	7.123	500	6, regularly increased.
3d. Class, 24 pdr. No. 301	1838	"	J. W. R.	{ 19897 20874 }	{ 6.967 7.085 }	208	

1st. Class.—Withstood all the tests without apparent injury. (*See NOTE, page 355.*)

2d. Class.—Fired to 500 rounds service charges, and burst at the 6th. increased charge, viz: with 6 pounds, 7 balls, and 2 wads.

Fracture through the vent.

3d. Class.—Burst at the 208th. round service charges, towards the close of the day's firing. It broke into three main fragments (as in gun No. 1), breaking off at the trunnions, and splitting through the vent, leaving one trunnion on the chase. PLATE XXIII, Fig. 2.

FIFTH SET—32 PDRS. *Suspended November 6, 1852.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
1st. Class, 32 pdr. No. 10	1841	West Point	W. M.	31734	7.245	500	15, regularly increased.
2d. Class, 32 pdr. No. 294	1834	"	J. B.	22284	7.196	318	
3d. Class, 32 pdr. No. 324	1839	"	J. W. R.	{ 18815 19323 }	{ 6.96 7.09 }	52	

1st. Class.—Withstood all the tests without injury.

2d. Class.—Burst at the 318th. fire, into three pieces, through the vent, and in front of the trunnions. The effect of the escaping blast on the rope and wood, seems to show that this gun opened on the right, in rear of the trunnions, and that the left half of the breech separated afterwards. The torsion of the chase, also, indicates that it was dragged round by the adhesion of the left half of the breech, after the separation of the right half.

3d. Class.—This gun burst at the 52d. fire, on the first day's firing. The fracture is excessively coarse, resembling pot metal. It is partially through the vent. It had been fired some rounds, and but a few, before its suspension, as appeared from the impression taken of the interior of the vent. PLATE XXIII, Fig. 3.

Fig. 1.

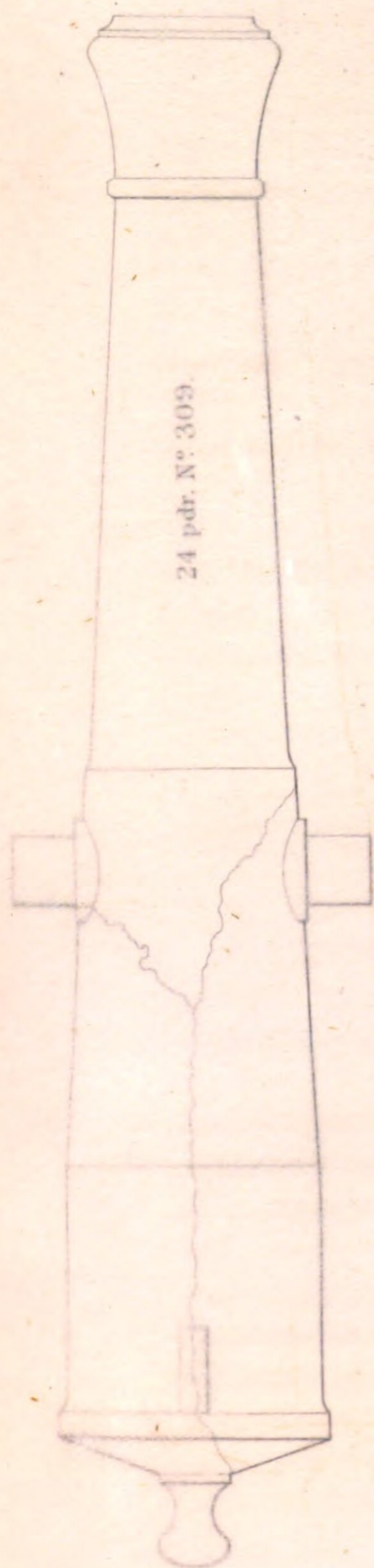


Fig. 2.

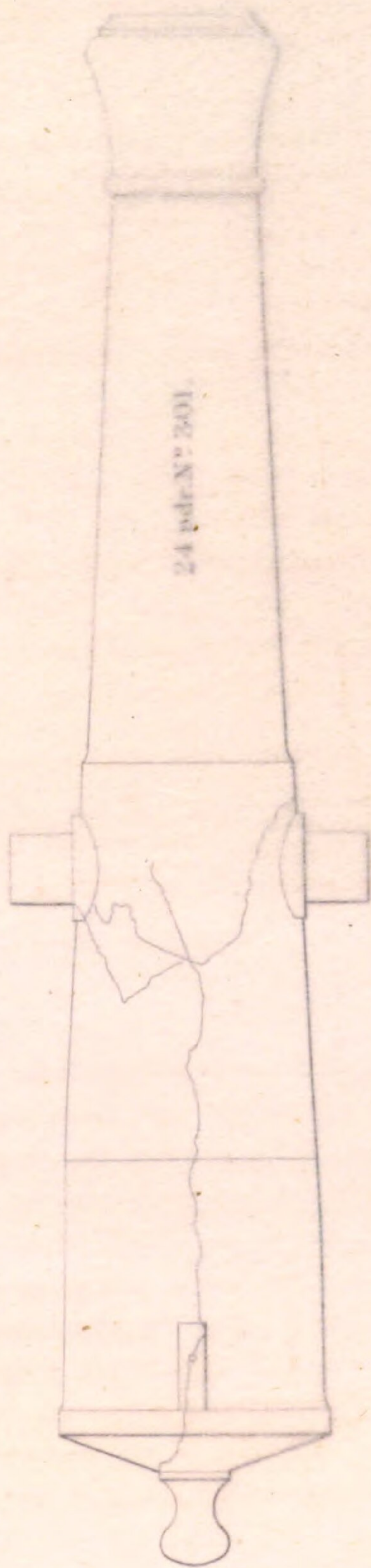
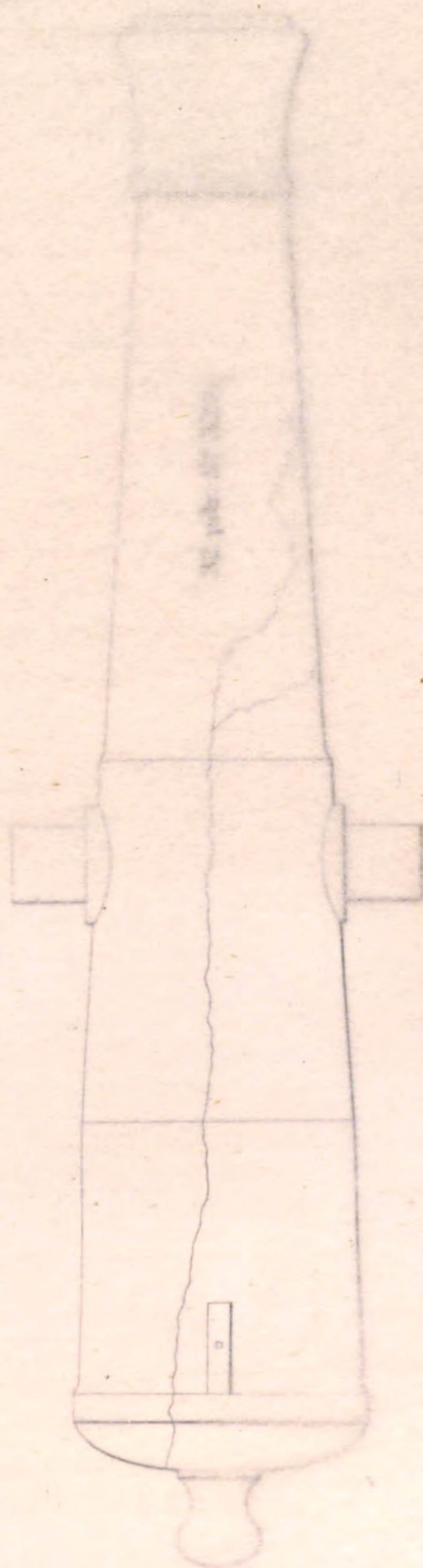


Fig. 3.



Scale 15.

Fifth Ser.—54 pdr. September October 25, 1852.

	Date	Prodr.	Signature	Weight	Specific gravity	Service rounds	Increased rounds
1st. Class, 54 pdr. No. 100 1852	West Point	J. B.	22225	7.199	500	16, regularly increased.	
2d. Class, 54 pdr. No. 200 1852	"	J. W. R.	22225	7.199	500	6, regularly increased.	
3d. Class, 54 pdr. No. 301 1852	"	J. W. R.	{ 22225 22274 }	{ 7.199 7.199 }	108		

1st. Class.—Withstood all the tests without apparent injury. (See Note, page 353.)

2d. Class.—Fired to 500 rounds service charges, and burst at the 5th. increased charge, viz. with 6 pounds, 1 balls, and 2 wads.

Fracture through the vent.

3d. Class.—Burst at the 208th. round service charges, towards the close of the day's firing. It broke into three main fragments (as in gun No. 1), breaking off at the transition, and splitting through the vent, leaving one specimen on the chase. Plate XXIII, Fig. 2.

Fifth Ser.—52 pdr. September November 6, 1852.

	Date	Prodr.	Signature	Weight	Specific gravity	Service rounds	Increased rounds
1st. Class, 52 pdr. No. 10	1843	West Point	W. M.	21734	7.340	500	16, regularly increased.
2d. Class, 32 pdr. No. 294	1834	"	J. B.	22284	7.196	500	
3d. Class, 32 pdr. No. 324	1839	"	J. W. R.	{ 18815 19322 }	{ 6.98 7.09 }	50	

1st. Class.—Withstood all the tests without injury.

2d. Class.—Burst at the 318th. fir., into three pieces. Through the vent, and to front of the chamber. The effect of the explosion burst on the right half, proved to show that the gun opened on the right, to rear of the chamber, and that the left half of the branch separated afterwards. The bottom of the right half, also, testifies that it was dragged round by the adhesion of the left half of the branch, after the separation of the right half.

3d. Class.—This gun burst at the 52d. fire, on the first day's firing. The fracture is extremely coarse, resembling pot metal. It is partially through the top. It had been fired some rounds, and but a few, before the explosion. The impression taken of the interior of the gun, shows the following:—

Fig. 1.

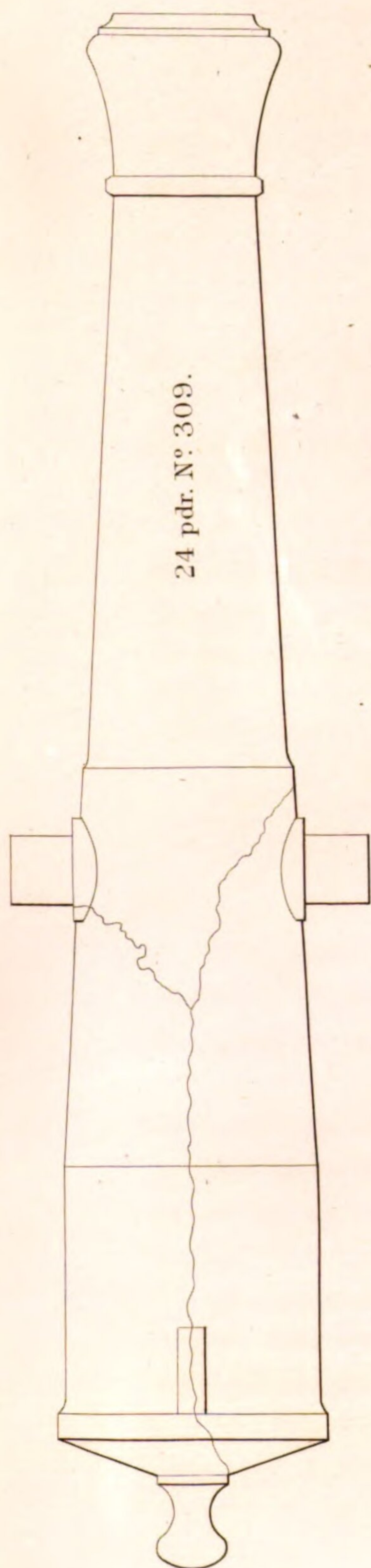


Fig. 2.

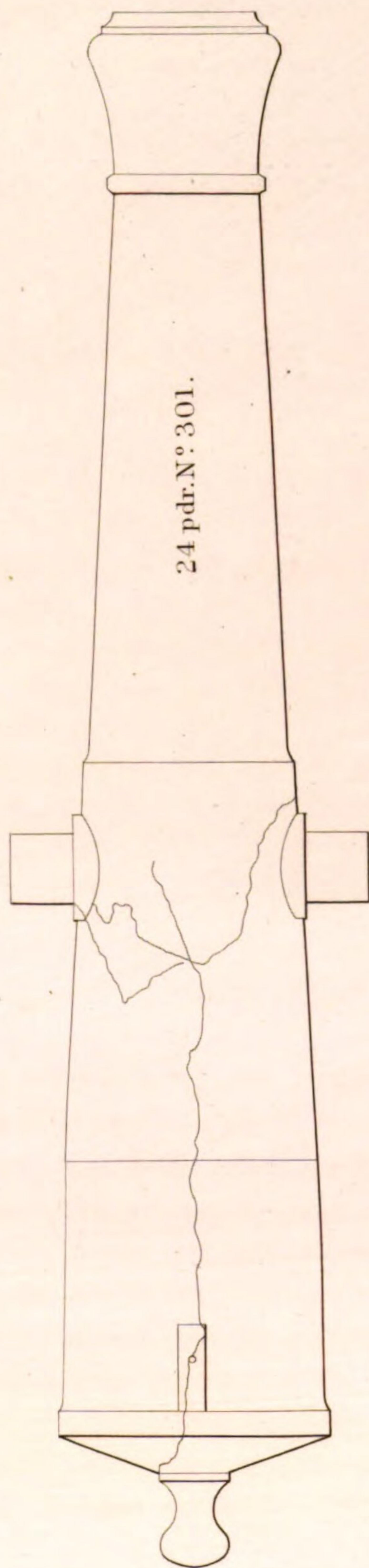
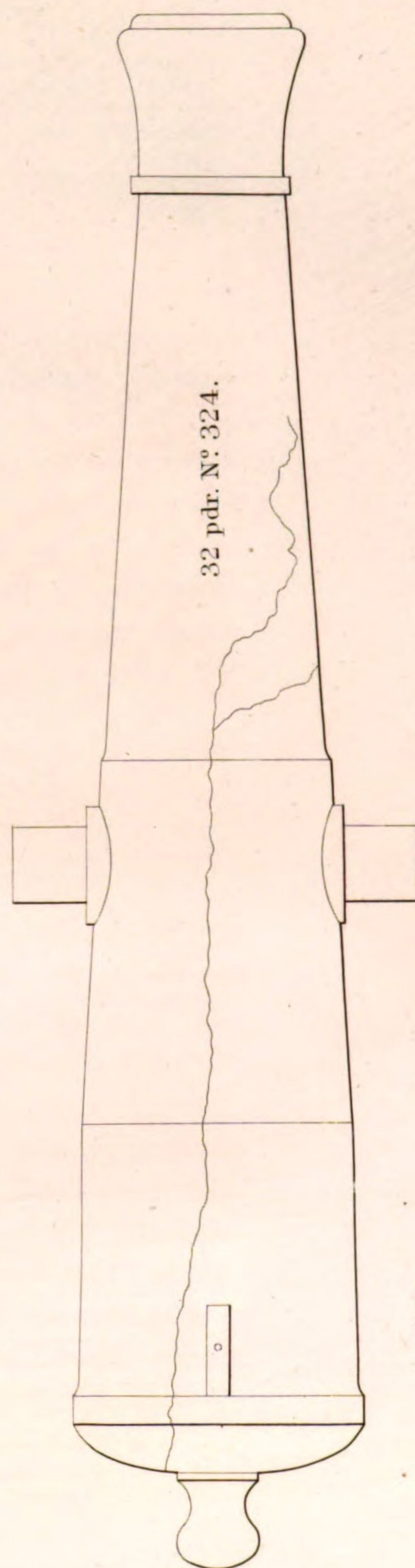


Fig. 3.



Scale 1/15.

SIXTH SET—32 PDRS. *Suspended December 6, 1852.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
1st. Class, 32 pdr. No. 11	1841	West Point	W. M.	31744	7.210	500	15, regularly increased.
2d. Class, 32 pdr. No. 63	1830	"	J. B.	23131	7.145	500	15, regularly increased.
3d. Class, 32 pdr. No. 325	1839	"	J. W. R.	{ 19464 20132 }	{ 7.024 6.922 }	112	

1st. and 2d. Class withstood all the tests. Both of these guns were washed within an hour after the firing of 68 rounds in 2½ hours. Temperature, perhaps 100°.

3d. Class.—Broke at the 112th. fire, at the close of the first day's firing. The fracture was nearly in the plane of the trunnions, and the pieces flew high into the air, breaking one leg of the frames near the top, and coming down close to the cover proof. Fracture exceedingly coarse; large cracks run off from the main break, at the chase—a very usual appearance in the bad guns. All the fragments fell to the right, and within an angle of 35° with the trunnions. PLATE XXIV, Fig. 1.

SEVENTH SET—32 PDRS. *Suspended December 29, 1852.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
1st. Class, 32 pdr. No. 137	1830	Bellona	J. B.	29337	7.19	500	15, regularly increased.
2d. Class, 32 pdr. No. 59	1829	"	J. B.	22425	7.264	500	12, regularly increased.
3d. Class, 32 pdr. No. 450	1839	"	J. W. R.	17348	7.108	89	

1st. Class.—Uninjured by the firing.

2d. Class.—Burst at the 12th. increased charge, with 13 balls, eight pounds of powder, and one wad. The fragments observed the usual direction of flight. The fracture, through the vent, and just in front of the trunnions.

3d. Class.—Burst at the 89th. service charge, the 28th. round of the day's firing. Fracture partially through the vent. The blast appeared to have escaped on the left side, by the charring of the rope and wood. PLATE XXIV, Fig. 2.

EIGHTH SET—32 PDRS. *Suspended January 17, 1853.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
1st. Class, 32 pdr. No. 136	1830	Bellona	J. B.	28780	7.17	500	15, regularly increased.
2d. Class, 32 pdr. No. 20	1829	"	J. B.	22570	7.232	500	13, regularly increased.
3d. Class, 32 pdr. No. 424	1836	"	J. W. R.	13405	7.14	800	15, regularly increased.

1st. Class.—Withstood all the tests. This and the following gun were both washed, while warm, in the course of the service firing.

2d. Class.—Burst at the 13th. increased charge, with 8 lbs., 14 balls, and 1 wad. Direction of fragments nearly like those of No. 59.

3d. Class.—Carried up to 800 rounds of service charges (agreeably to the instructions), and withstood all the increased charges—notwithstanding the small tensile strength of the record.*

The temperature of this gun rose to 110°, after firing 190 rounds in the course of 8 or 9 hours; the thermometer placed in the bore, 2½ feet from the muzzle. This was the highest temperature observed. Thermometer, in the shade, 62°.

NINTH SET—8 INCH COLUMBIADS. *Suspended February 10, 1853.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
8 inch Columbiad, No. 19	1846	Boston	J. W. R.	36497	7.333	500	11, regularly increased.
8 inch Columbiad, No. 33	1845	West Point	R. L. B.	29252	7.317	500	4, regularly increased.

No. 19 withstood all the tests. The bore of this gun was carefully examined at the 9th. round, and after the last, but no defects discovered.

* Since the trial of this Gun, samples have been taken from the muzzle, breech, and front of trunnions, and tested for density and tenacity, by Lieut. McAllister, Ordnance. The results obtained show that the true sample of this gun was probably misplaced.

Density and Tensile Strength of 32 pdr. No. 424, B. F.

	Density.	Tensile strength per sq. inch.
Muzzle Sample (<i>M</i>)	7.164	16930
Breech Sample (<i>B</i>)	7.256	22009
Front of Trunnions Sample (<i>T</i>)	7.076	20739

The character of the fracture, Lieut. McAllister reports, indicates "good metal, not very high." The Record-Book ascribes a very different appearance to the sample therein referred to, as belonging to this Gun.

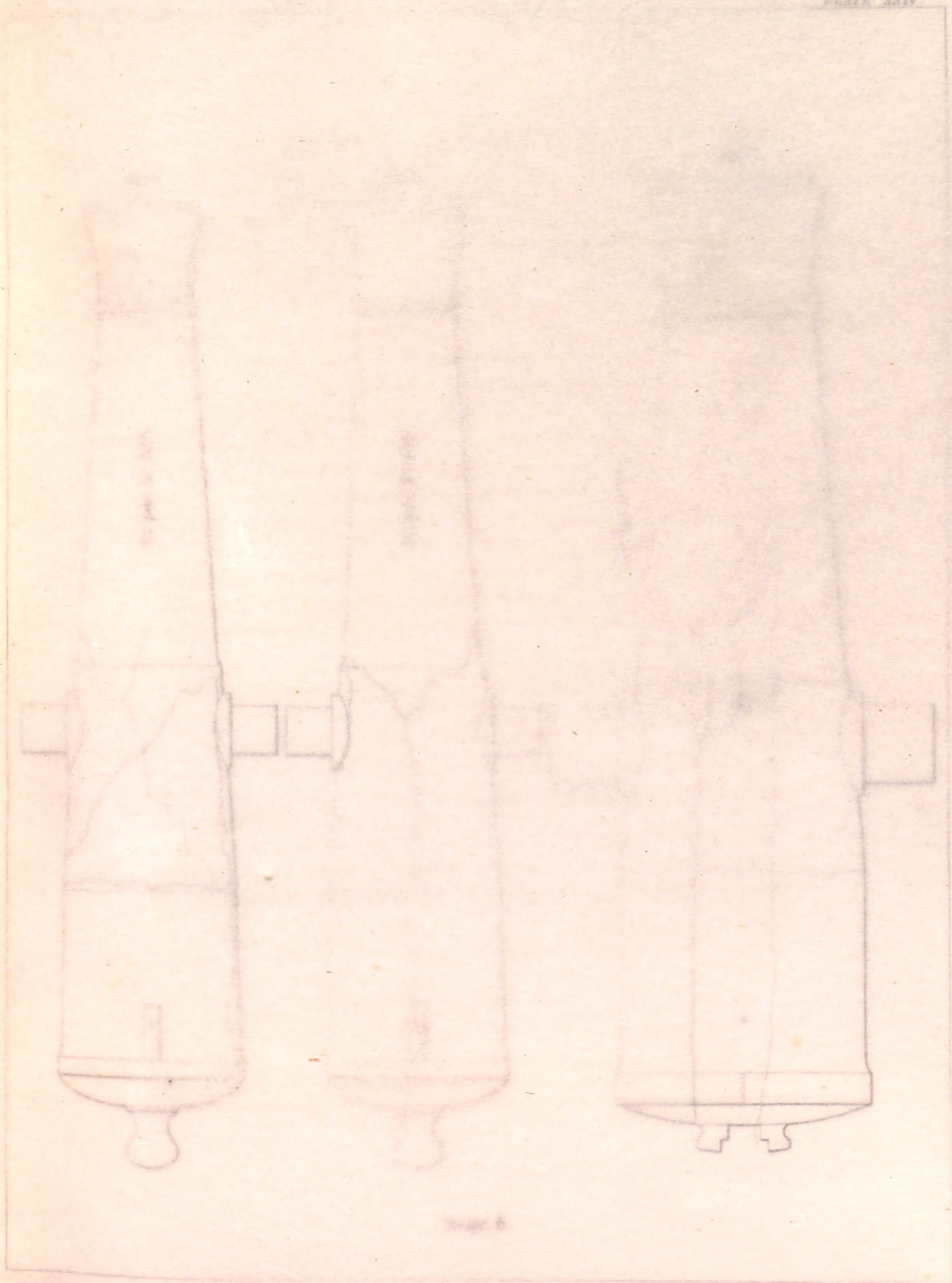


Fig. 1

Report No. 11, 1853. Suspended January 17, 1853.

No.	Design.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
No. 11, 1853.	No. 11, 1853.	J. W. H.	26497	1.333	500	15, regularly increased.
No. 12, 1853.	No. 12, 1853.	J. W. H.	26497	1.333	500	13, regularly increased.
No. 13, 1853.	No. 13, 1853.	J. W. H.	26497	1.333	500	15, regularly increased.

No. 11, 1853.—Withstood all the tests. This and the following gun were not tested, when under the stress of the service firing.

No. 12, 1853.—Fired at the 14th. increased charge, with 8 lbs., 14 balls, and 1 shot. The character of fragments exactly like those of No. 53.

No. 13, 1853.—Fired up to 500 rounds of service charges (agreeably to the instructions) and withstood all the increased charges—notwithstanding the great wear and tear of the record.*

The temperature of this gun rose to 110° , after firing 190 rounds in the course of 8 or 9 hours; the thermometer placed in the bore, 24 feet from the muzzle. This was the highest temperature observed. Thermometer, in the shade, 87° .

Report No. 12, 1853. Suspended February 10, 1853.

No.	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
8 inch Columbiad, No. 19	1846	Hoston	J. W. H.	26497	1.333	500	11, regularly increased.
8 inch Columbiad, No. 33	1845	West Point	H. L. H.	26497	1.333	500	1, regularly increased.

No. 19 withstood all the tests. The bore of this gun was carefully examined at the 9th. round, and after the last, but no defects discovered.

* Since the trial of this Gun, samples have been taken from the muzzle, breech, and front of trunnions, and tested for density and tenacity, by Lieut. McAllister, Ordnance. The results obtained show that the true sample of this gun was probably misplaced.

Density and Tensile Strength of 32 pdr. No. 424, H. F.

Sample	Density	Tensile Strength
Muzzle Sample (M)	7.154	26497
Breech Sample (B)	7.156	26497
Front of Trunnions Sample (T)	7.079	26497

The character of the fracture, Lieut. McAllister reports, indicates "good metal, but not high." The Record-Book ascribes a very different appearance to the sample taken from the muzzle, as belonging to this Gun.

Fig. 1.

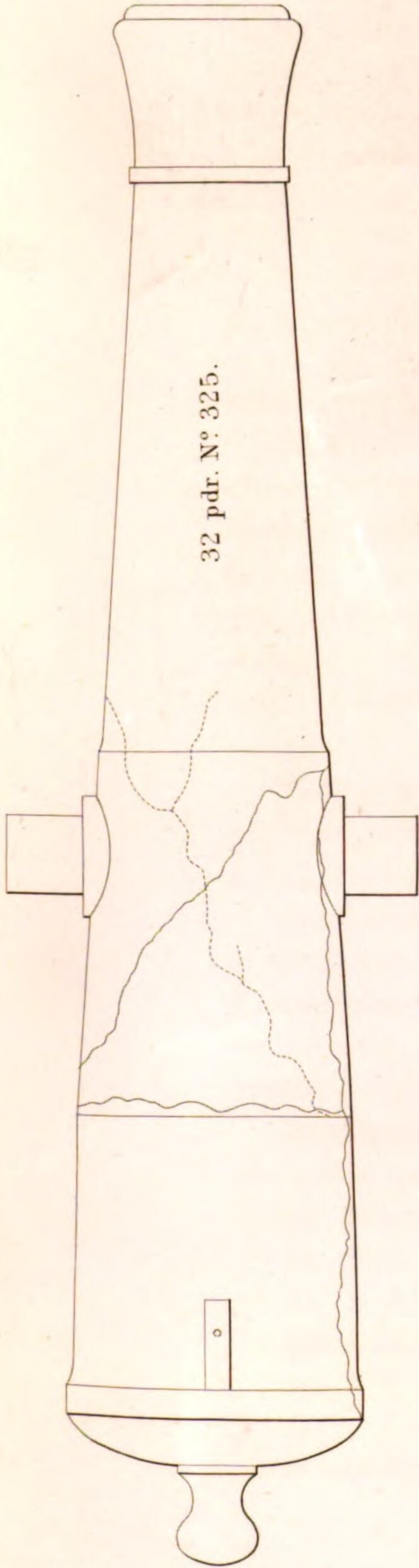


Fig. 2.

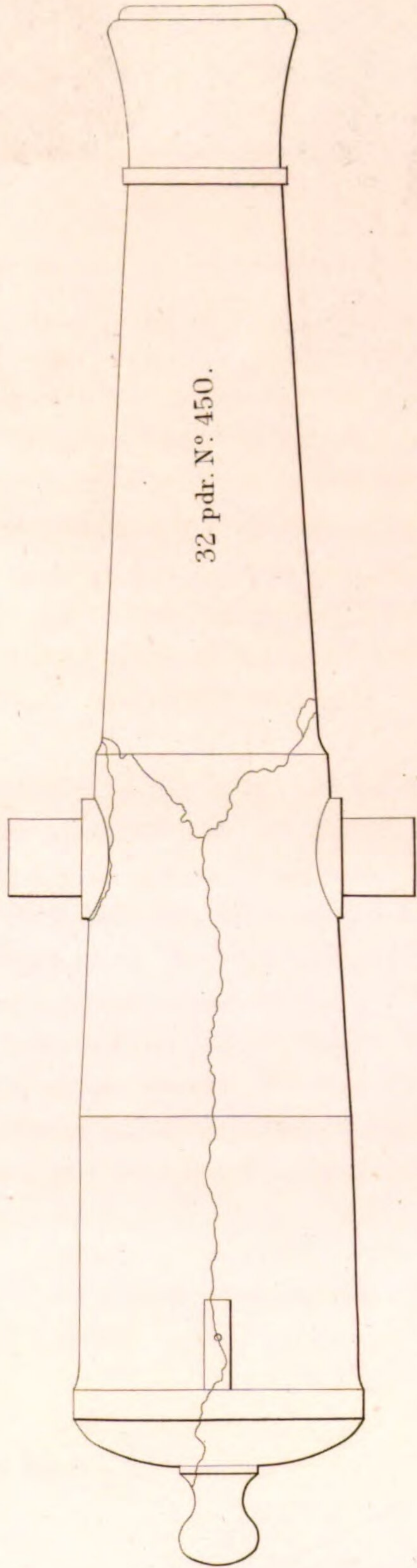
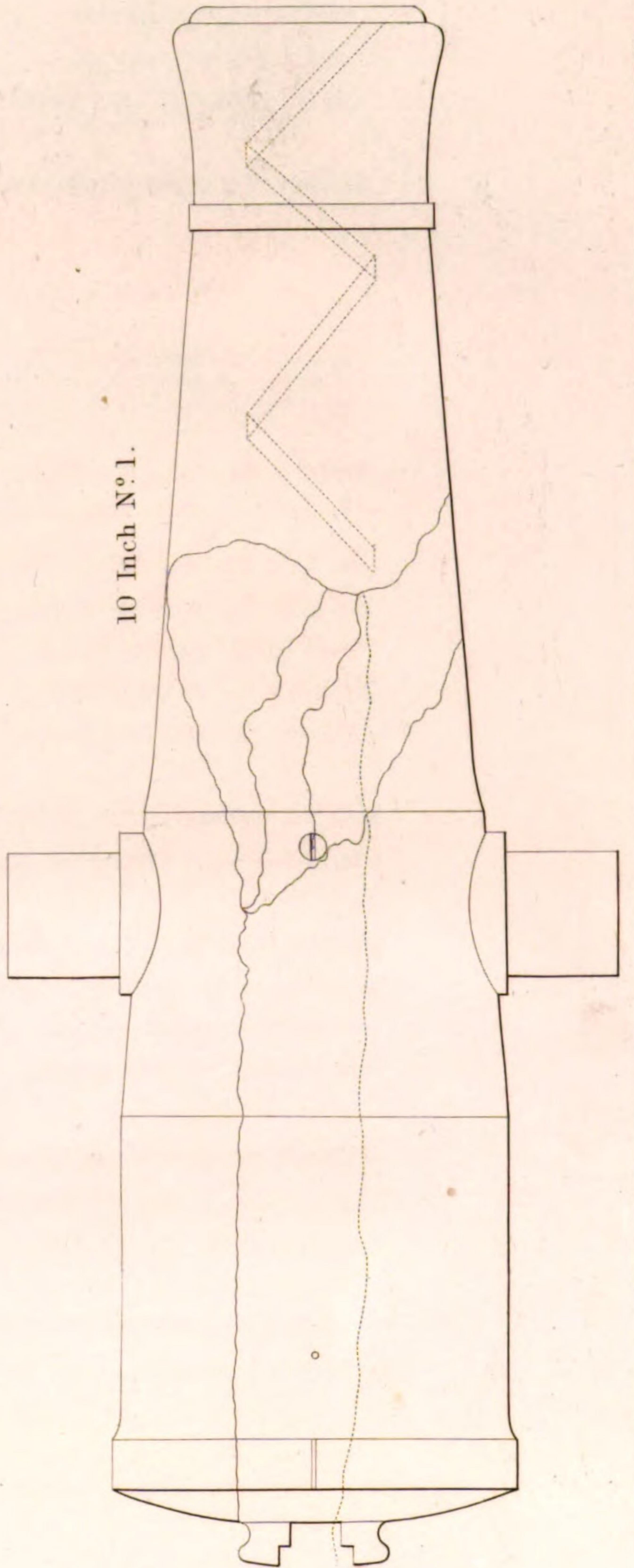


Fig. 3.



Scale 1/3.

The first of these is the fact that the United States is a young nation, and its history is therefore a history of growth and development. The second is the fact that the United States is a large nation, and its history is therefore a history of expansion and conquest.

The third is the fact that the United States is a diverse nation, and its history is therefore a history of conflict and compromise. The fourth is the fact that the United States is a nation of immigrants, and its history is therefore a history of assimilation and adaptation.

The fifth is the fact that the United States is a nation of pioneers, and its history is therefore a history of exploration and discovery. The sixth is the fact that the United States is a nation of inventors, and its history is therefore a history of innovation and progress.

The seventh is the fact that the United States is a nation of reformers, and its history is therefore a history of social and political change. The eighth is the fact that the United States is a nation of idealists, and its history is therefore a history of aspiration and hope.

The ninth is the fact that the United States is a nation of dreamers, and its history is therefore a history of vision and imagination. The tenth is the fact that the United States is a nation of doers, and its history is therefore a history of action and achievement.

The eleventh is the fact that the United States is a nation of leaders, and its history is therefore a history of guidance and inspiration. The twelfth is the fact that the United States is a nation of followers, and its history is therefore a history of obedience and loyalty.

The thirteenth is the fact that the United States is a nation of citizens, and its history is therefore a history of participation and responsibility. The fourteenth is the fact that the United States is a nation of voters, and its history is therefore a history of choice and decision.

The fifteenth is the fact that the United States is a nation of taxpayers, and its history is therefore a history of contribution and sacrifice. The sixteenth is the fact that the United States is a nation of soldiers, and its history is therefore a history of service and duty.

The seventeenth is the fact that the United States is a nation of sailors, and its history is therefore a history of exploration and discovery. The eighteenth is the fact that the United States is a nation of farmers, and its history is therefore a history of production and sustenance.

The nineteenth is the fact that the United States is a nation of workers, and its history is therefore a history of labor and industry. The twentieth is the fact that the United States is a nation of entrepreneurs, and its history is therefore a history of risk and reward.

The twenty-first is the fact that the United States is a nation of scientists, and its history is therefore a history of knowledge and discovery. The twenty-second is the fact that the United States is a nation of artists, and its history is therefore a history of creativity and expression.

The twenty-third is the fact that the United States is a nation of writers, and its history is therefore a history of thought and communication. The twenty-fourth is the fact that the United States is a nation of thinkers, and its history is therefore a history of reflection and analysis.

The twenty-fifth is the fact that the United States is a nation of leaders, and its history is therefore a history of vision and inspiration. The twenty-sixth is the fact that the United States is a nation of followers, and its history is therefore a history of obedience and loyalty.

The twenty-seventh is the fact that the United States is a nation of citizens, and its history is therefore a history of participation and responsibility. The twenty-eighth is the fact that the United States is a nation of voters, and its history is therefore a history of choice and decision.

The twenty-ninth is the fact that the United States is a nation of taxpayers, and its history is therefore a history of contribution and sacrifice. The thirtieth is the fact that the United States is a nation of soldiers, and its history is therefore a history of service and duty.

The thirty-first is the fact that the United States is a nation of sailors, and its history is therefore a history of exploration and discovery. The thirty-second is the fact that the United States is a nation of farmers, and its history is therefore a history of production and sustenance.

The thirty-third is the fact that the United States is a nation of workers, and its history is therefore a history of labor and industry. The thirty-fourth is the fact that the United States is a nation of entrepreneurs, and its history is therefore a history of risk and reward.

No. 33.—Broke at the fourth increased charge, with 10 pounds powder 5 balls, and 1 wad. Fracture through the vent, and in front of trunnions. The pieces of the breech were thrown to the distance of 70 yards, in the usual direction.

This gun was *bouched* at 430 rounds, with a bouche $1\frac{1}{4}$ diameter, and $1\frac{1}{2}$ inches long.

TENTH SET—10 INCH COLUMBIADS. *Suspended March 20, 1853.*

	Date.	Foundry.	Inspector's initials.	Tensile strength.	Specific gravity.	Service rounds.	Increased rounds.
10 inch Columbiad, No. 1	1846	Boston	J. W. R.	36000	7.312	94	
10 inch Columbiad, No. 2	1845	West Point	R. L. B.	29181	7.416	500	9, regularly increased.

No. 1, 10 inch Columbiad.—This gun burst, at the 94th. service round, into three pieces, at $3\frac{1}{2}$ feet from the muzzle, and in a plane through the axis making an angle of 30° with the vertical plane. The bore of the chase shows a distinct spiral mark of the sabot, for two entire turns, of about 22 inches to each turn. PLATE XXIV, Fig. 3. The ball was found in the butt uninjured.

No. 2.—Withstood all the tests. At the seventh round, the bore of this gun was carefully examined with the mirror, but no cracks were detected; nor did the bore appear to be at all injured.

In attempting to bore out the wooden vent-plug of this gun, a portion of the gimlet broke off in the vent, and resisted every effort to remove it. In consequence, a new vent was drilled at a few inches distance from the old one; this latter still continues effectually spiked, having resisted the force of even the double charge.

In the progress of the drilling, various degrees of hardness were encountered in the metal, and were noted in the following order:—

- 1st. of 1 inch, hard.
- 2d. “ $2\frac{1}{2}$ “ softer.
- 3d. “ $2\frac{1}{2}$ “ very hard, requiring the drill to be frequently sharpened.
- 4th. “ $2\frac{3}{4}$ “ softer.
- 5th. “ 2 “ hard.
- 6th. “ 1 “ soft.
- Remainder, hard.

B.

Table showing the Order of "Tensile Strength," and that of "Endurance," of the 24 and 32 pdr. Test Guns.

	Order of tensile strength.	Order of endur- ance.	Tensile strength.	No. of gun.	Class	Foundry.	Service charges.	Increased charges.
24 pdrs.	1	5	29055	40	1	Bellona	500	Burst at 14th., regularly increased.
	2	9	28208	1	1	"	371	
	4	1	28067	186	1	West Point	500	16, regularly increased, not burst. (See Note, p. 355.)
	3	4	28208	193	1	"	500	Burst at 16th., regularly increased.
	5	10	23836	287	2	"	277	
	6	7	23413	290	2	"	500	Burst at 6th., regularly increased.
	7	8	23272	163	2	Bellona	409	
	8	2	22566	7	2	"	539	{ 15, regularly increased. 6, 12 lbs. powder and 16 balls. } Burst 10, 18 lbs. powder, 10 } at last to 14 balls. } fire.
	9	11	20874	301	3	West Point	208	
	10	12	20028	309	3	"	148	
	11	3	19040	173	3	Bellona	800	Burst at 16th., regularly increased.
	12	6	14104	174	3	"	500	Burst at 13th., regularly increased.
32 pdrs.	1	2	31744	11	1	West Point	500	15, regularly increased, not burst.
	3	2	29337	137	1	Bellona	500	15, regularly increased; not burst.
	4	2	28780	136	1	"	500	15, regularly increased, not burst.
	2	2	31734	10	1	West Point	500	15, regularly increased, not burst.
	5	2	23131	63	2	"	500	15, regularly increased, not burst.
	6	5	22284	294	2	"	318	
	7	3	22570	20	2	Bellona	500	Burst at 13th., regularly increased.
	8	4	22425	59	2	"	500	Burst at 12th., regularly increased.
	9	6	{ 19464 20132 }	325	3	West Point	112	
	10	8	{ 19323 18815 }	324	3	"	52	
	11	7	17348	450	3	Bellona	89	
	12	1	13405	424	3	"	800	15, regularly increased, not burst.

NOTE.—The subsequent firing of gun No. 186 shows it to have been inferior in endurance to No. 7. The numbers of these two guns should, therefore, be interchanged.

C.

*Statement showing the Quantity of Powder fired, and the Weight of Metal thrown,
from each Class.*

Classes.	No. of guns.	CALIBRE.		Service rounds.	Increased rounds.	Quantity of powder.	Weight of shot.	Remarks.
		24 pdr.	32 pdr.					
1st.	8	4	4	3871	106	Lbs. 27994	Lbs. 136512	3, 24 pdr. guns burst.
2d.	8	4	4	3543	77	25568	119056	4, 24 pdr. and 3, 32 pdr. guns burst.
3d.	8	4	4	2709	45	18640	79614	4, 24 pdr. and 3, 32 pdr. guns burst.
COLUMBIADS.								
1st.	2	8 inch.	10 in.	1000	15	10160	70918	One gun burst.
1st.	2	—	2	694	9	10872	82816	One gun burst.
Total	28	—	—	11817	252	93234	488916	

Total Burst.

	24 pdr.	32 pdr.	Total.
1st. class	3	—	3
2d. class	4	3	7
3d. class	4	3	7
	11	6	17
10 inch Columbiad			1
8 inch Columbiad			1
			19

D.

Enlargements of the Bores of various Iron Guns.

Distance from muzzle in inches	100	99½	99	98½	98	97½	97	96½	96	95½	95	94½	94	93½	93	92½	92	91½	91	90½	90
Class 2d., 24 pdr. No. 7, B. F., 508 rounds	.004	.000	.014	.026	.018	.015	.008	.006	.008	.000	.002	.003	.000	.011	.005	.001	.000	.002	.004	.000	.000
Class 3d., 24 pdr. No. 173, B. F., 800 rounds	.009	.025	.035	.034	.046	.089	.036	.022	.022	.005	.026	.019	.014	.024	.035	.015	.008	.006	.000	.000	.002
Class 1st., 24 pdr. No. 40, B. F., 500 rounds	.006	.006	.008	.007	.004	.004	.009	.018	.015	.014	.012	.010	.011	.003	.004	.001	.003	.002	.002	.002	.000
Class 3d., 24 pdr. No. 174, B. F., 500 rounds	.015	.000	.006	.010	.057	.038	.032	.000	.020	.001	.029	.065	.062	.045	.018	.007	.010	.012	.010	.008	.007
Class 1st., 24 pdr. No. 193, W. P. F., 500 rounds	.006	.005	.005	.005	.007	.015	.005	.003	.009	.006	.000	.005	.000	.002	.003	.004	.005	.007	.004	.005	.012
Class 1st., 24 pdr. No. 186, W. P. F., 500 rounds	.001	.001	.001	.000	.007	.004	.003	.004	.005	.007	.004	.005	.002	.003	.003	.004	.005	.003	.000	.007	.004
Class 2d., 24 pdr. No. 290, W. P. F., 500 rounds	.004	.001	.003	.007	.009	.012	.005	.004	.004	.007	.007	.006	.007	.007	.010	.005	.000	.000	.001	.000	.000
Class 1st., 32 pdr. No. 11, W. P. F., 500 rounds	.006	.008	.014	.014	.010	.008	.014	.028	.029	.010	.024	.027	.030	.037	.033	.029	.026	.021	.009	.007	.011
Class 2d., 32 pdr. No. 63, W. P. F., 500 rounds	.007	.010	.008	.011	.011	.011	.013	.026	.034	.017	.007	.006	.011	.008	.010	.012	.010	.013	.000	.010	.013
Class 1st., 32 pdr. No. 137, B. F., 500 rounds	.008	.010	.008	.007	.005	.023	.033	.040	.023	.014	.012	.012	.010	.015	.012	.012	.012	.014	.012	.010	.019
Class 2d., 32 pdr. No. 59, B. F., 500 rounds	.016	.013	.012	.014	.012	.022	.043	.046	.037	.016	.013	.013	.014	.015	.016	.015	.017	.018	.015	.016	.008
Class 1st., 32 pdr. No. 136, B. F., 500 rounds	.007	.008	.004	.008	.006	.003	.022	.021	.010	.008	.013	.012	.010	.010	.010	.008	.007	.010	.010	.010	.007
Class 2d., 32 pdr. No. 20, B. F., 500 rounds	.006	.005	.006	.008	.009	.014	.023	.023	.014	.008	.010	.009	.007	.009	.011	.012	.011	.015	.012	.014	.012
Class 3d., 32 pdr. No. 424, B. F., 500 rounds	.024	.027	.025	.027	.024	.045	.055	.060	.051	.025	.029	.029	.030	.027	.030	.030	.029	.028	.028	.029	.029
Distances from muzzle in inches	92	91½	91	90½	90	89½	89	88½	88	87½	87	86½	86	85½	85	84½	84	83	82	81	80
8 inch Columbiad No. 19, C. A. & Co., after extreme firing	.023	.020	.015	.015	.000	.003	.010	.010	.005	.008	.013	.020	.024	.020	.016	.014	.012	.015	.012	.012	.007
Class 1st., 8 inch Columbiad, W. P. F., 500 rounds	.016	.015	.010	.015	.012	.009	.009	.009	.009	.013	.008	.008	.008	.010	.012	.008	.014	.010	.011	.012	.010
Class 1st., 10 inch Columbiad, W. P. F., 500 rounds	.063	.055	.032	.025	.022	.008	.006	.017	.024	.036	.012	.015	.014	.012	.007	.015	.022	.007	.004	.017	.009

Enlargements of the Bores of various Iron Guns—Continued.

Distance from muzzle in inches	89½	89	88½	88	87½	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72
Class 2d., 24 pdr. No. 7, B. F., } 508 rounds	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Class 3d., 24 pdr. No. 173, } B. F., 800 rounds	.003	.010	.005	.010	.000	.008	.006	.001	.011	.067	.010	.022	.000	.011	.054	.021	.080	.002	.002	.012	.009
Class 1st., 24 pdr. No. 40, } B. F., 500 rounds	.000	.003	.000	.000	.000	.005	.000	.004	.002	.008	.010	.019	.000	.002	.000	.000	.002	.000	.000	.000	.000
Class 3d., 24 pdr. No. 174, } B. F., 500 rounds	.007	.014	.009	.004	.004	.004	.011	.014	.004	.025	.006	.010	.022	.035	.000	.015	.008	.009	.012	.013	.005
Class 1st., 24 pdr. No. 193, } W. P. F., 500 rounds	.004	.004	.004	.008	.010	.000	.001	.001	.001	.001	.000	.009	.001	.002	.003	.004	.002	.002	.004	.003	.004
Class 1st., 24 pdr. No. 186, } W. P. F., 500 rounds	.002	.005	.003	.006	.007	.007	.004	.008	.004	.004	.003	.003	.002	.002	.003	.002	.002	.003	.003	.002	.001
Class 2d., 24 pdr. No. 290, } W. P. F., 500 rounds	.000	.003	.003	.001	.003	.005	.002	.000	.000	.003	.005	.001	.000	.001	.000	.001	.002	.002	.002	.002	.003
Class 1st., 32 pdr. No. 11, } W. P. F., 500 rounds	.018	.017	.015	.018	.014	.012	.009	.008	.007	.006	.012	.011	.011	.009	.010	.015	.016	.016	.010	.012	.013
Class 2d., 32 pdr. No. 63, } W. P. F., 500 rounds	.010	.013	.008	.004	.003	.004	.000	.003	.012	.007	.004	.012	.007	.008	.008	.001	.002	.010	.010	.005	.008
Class 1st., 32 pdr. No. 137, } B. F., 500 rounds	.017	.015	.018	.018	.016	.011	.008	.016	.008	.013	.009	.008	.007	.010	.009	.011	.012	.008	.009	.007	.007
Class 2d., 32 pdr. No. 59, } B. F., 500 rounds	.015	.015	.015	.008	.021	.014	.014	.016	.013	.012	.015	.008	.012	.014	.016	.012	.011	.008	.009	.011	.010
Class 1st., 32 pdr. No. 136, } B. F., 500 rounds	.009	.008	.009	.007	.007	.007	.007	.008	.008	.009	.006	.007	.008	.006	.003	.003	.005	.005	.003	.004	.003
Class 2d., 32 pdr. No. 20, } B. F., 500 rounds	.012	.014	.012	.012	.014	.015	.007	.005	.003	.004	.009	.010	.011	.010	.011	.007	.010	.016	.008	.014	.015
Class 3d., 32 pdr. No. 424, } B. F., 500 rounds	.029	.029	.029	.027	.027	.027	.027	.026	.026	.034	.034	.029	.018	.020	.022	.025	.029	.021	.019	.013	.016
Distances from muzzle in inches	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	55
8 inch Columbiad No. 19, C. A. } & Co., after extreme firing	.020	.020	.015	.015	.016	.017	.017	.013	.012	.025	.007	.015	.010	.015	.010	.010	.014	.012	.012	.010	.012
Class 1st., 8 inch Columbiad, } W. P. F., 500 rounds	.009	.009	.007	.008	.007	.008	.009	.009	.007	.007	.006	.005	.008	.008	.007	.007	.009	.011	.012	.012	.010
Class 1st., 10 inch Columbiad, } W. P. F., 500 rounds	.007	.003	.004	.003	.004	.006	.007	.007	.007	.007	.004	.007	.008	.008	.007	.007	.003	.008	.008	.007	.007

[illegible]

E.

Table of the Exterior of the Vents of several of the Iron Test Guns, at intervals of 100 rounds.

No.	Class.	0.	100.	200.	300.	400.	500.	800.	Remarks.
24 pdrs.	1	1	.275	—	—	—	.5	—	At 371 when gun burst.
	7	2	.25	—	—	—	—	—	
	173	3	.2	—	—	—	—	.55	Slightly irregular.
	40	1	.2	—	—	.33	.35	.4	
	163	2	.2	—	—	.33	.35	—	Vent worn nearly round.
	174	3	.2	—	—	.32	.37	.4	Vent slightly elongated.
	193	1	.2	.25	.3	.35	—	.42	Vent worn round.
	287	2	.2	.25	.3	—	—	—	Broke at 277.
	309	3	.2	.25	—	—	—	—	Broke at 148.
	186	1	.2	—	—	.33	.36	.44	Slightly elongated and irregular.
	290	2	.2	—	—	.33	.38	.42	.02 inch elongation.
32 pdrs.	11	1	.2	.23	—	.35	.4	.48	Irregular, greatest diameter oblique to axis.
	63	2	.23	.28	—	.35	.42	.46	Slightly elongated.
	325	3	.23	.28	—	—	—	—	Burst at 112.
	137	1	.2	.28	—	.35	.38	—	
	59	2	.2	.28	—	.4	.45	.54	Vent slightly elongated.
	136	1	.2	.25	—	.3	.4	—	
	20	2	.2	.27	—	.3	.43	—	Quite round.
	424	3	.2	—	.27	.3	—	.36	Slightly irregular.
	19	8 in.	.2	.24	—	.35	.4	—	Slightly irregular.
	33	8 in.	.2	.24	—	.45	.6	—	Very irregular, bouched at 430.
	2	10 in.	.2	.25	—	—	.45	—	Very irregular, largest diameter nearly transverse.
Average size		—	.26	.29	.342	.403	.436	.535	

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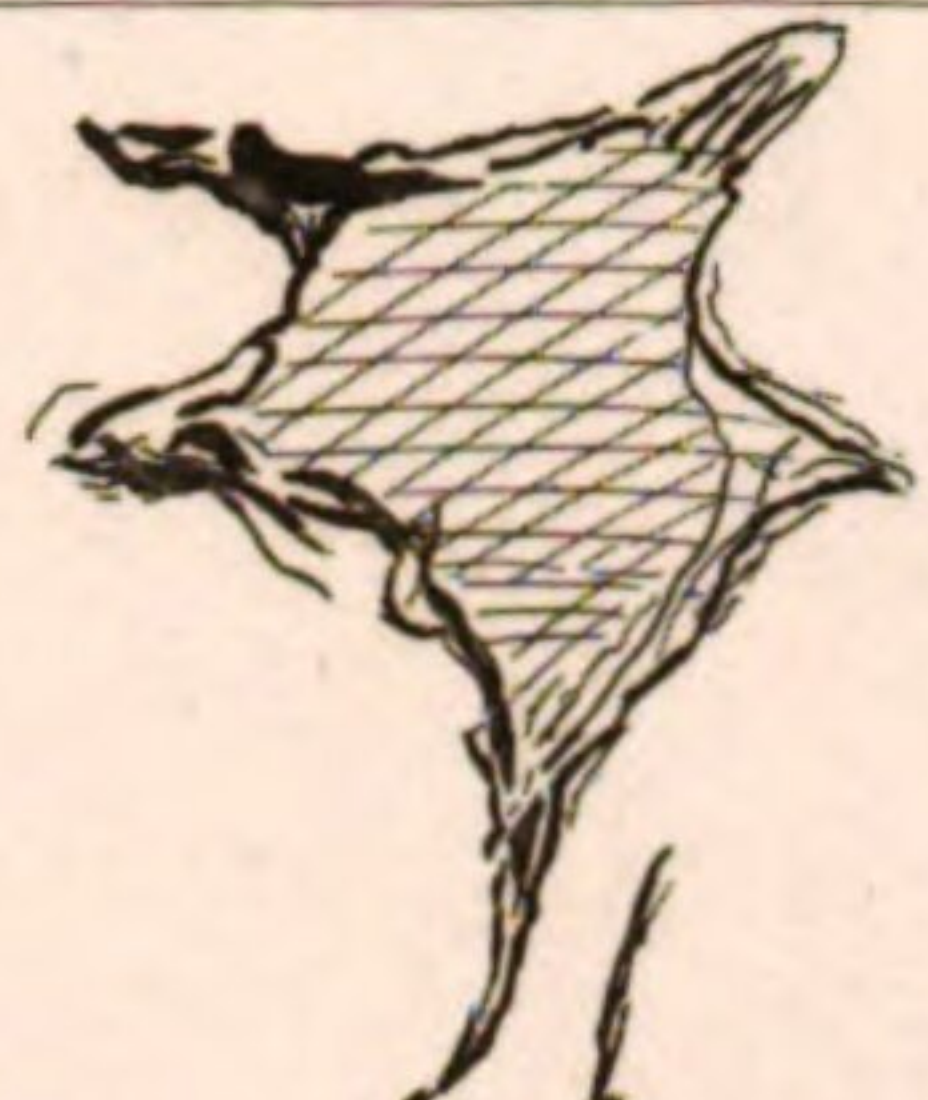
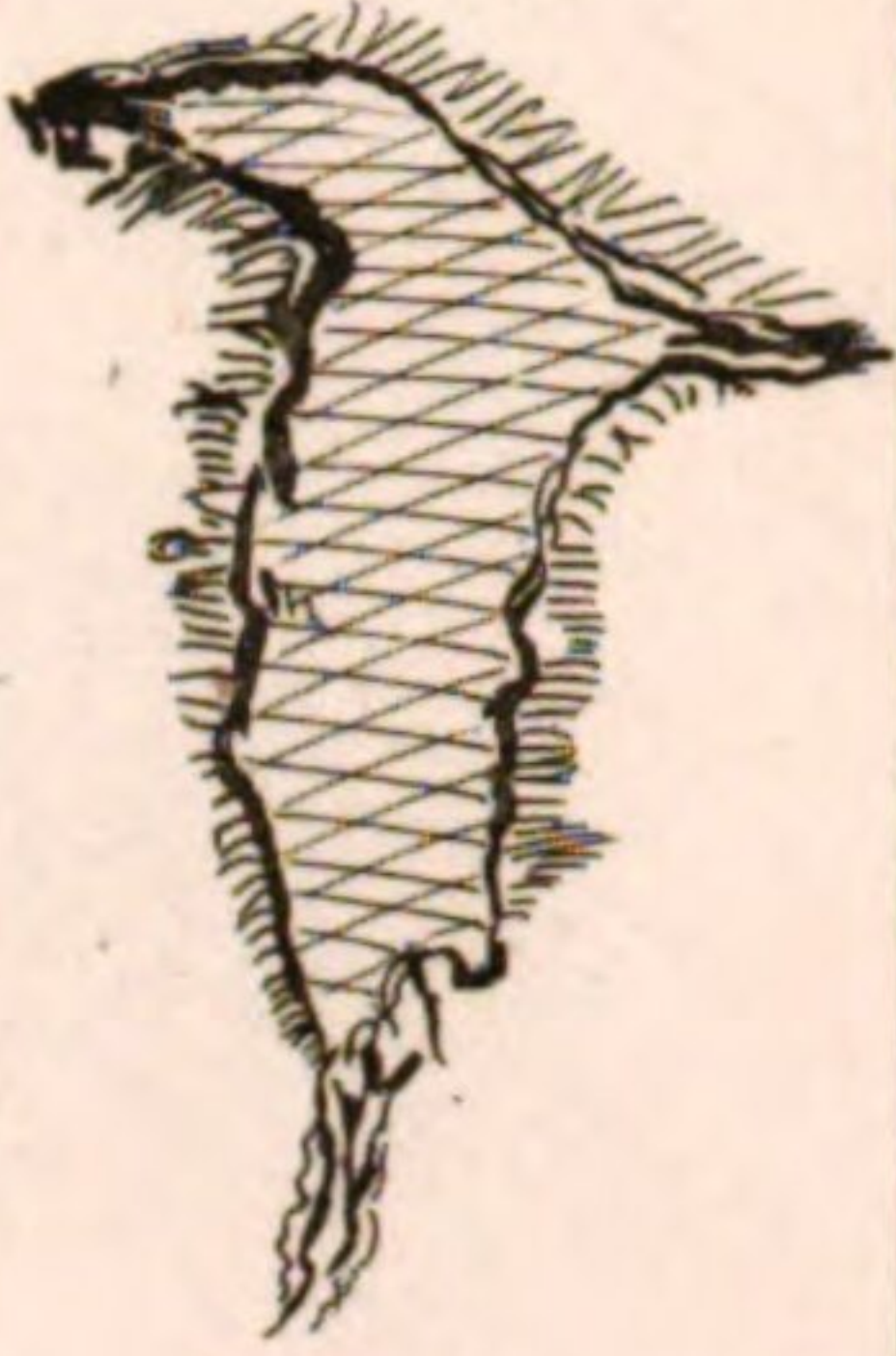
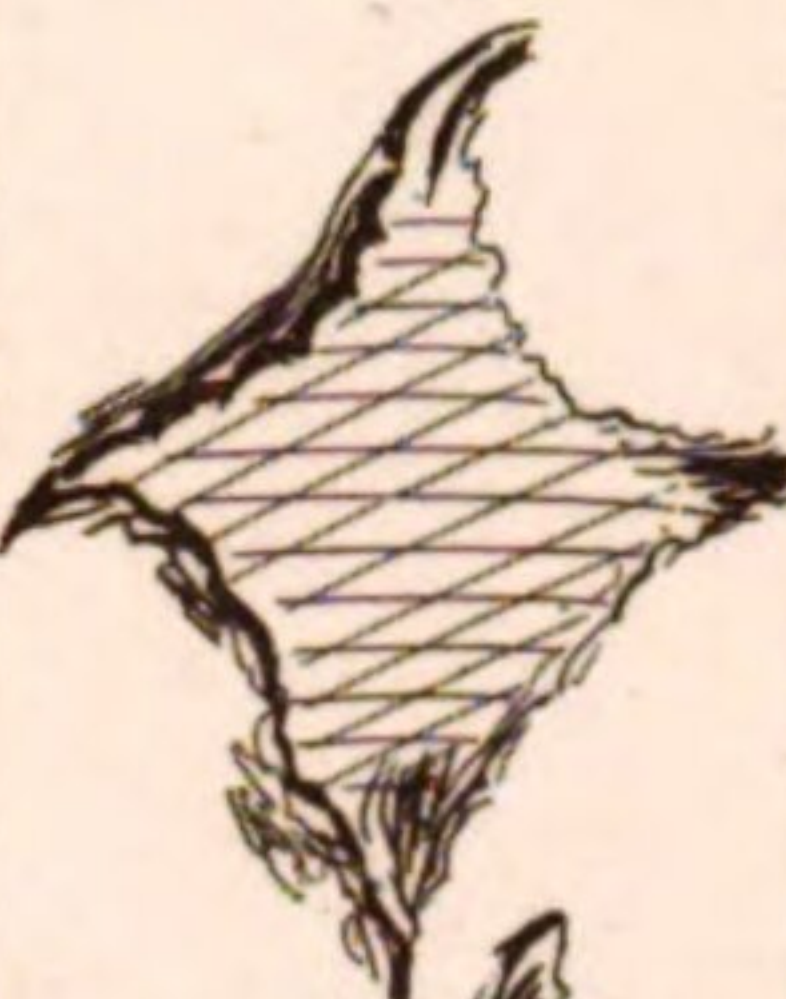
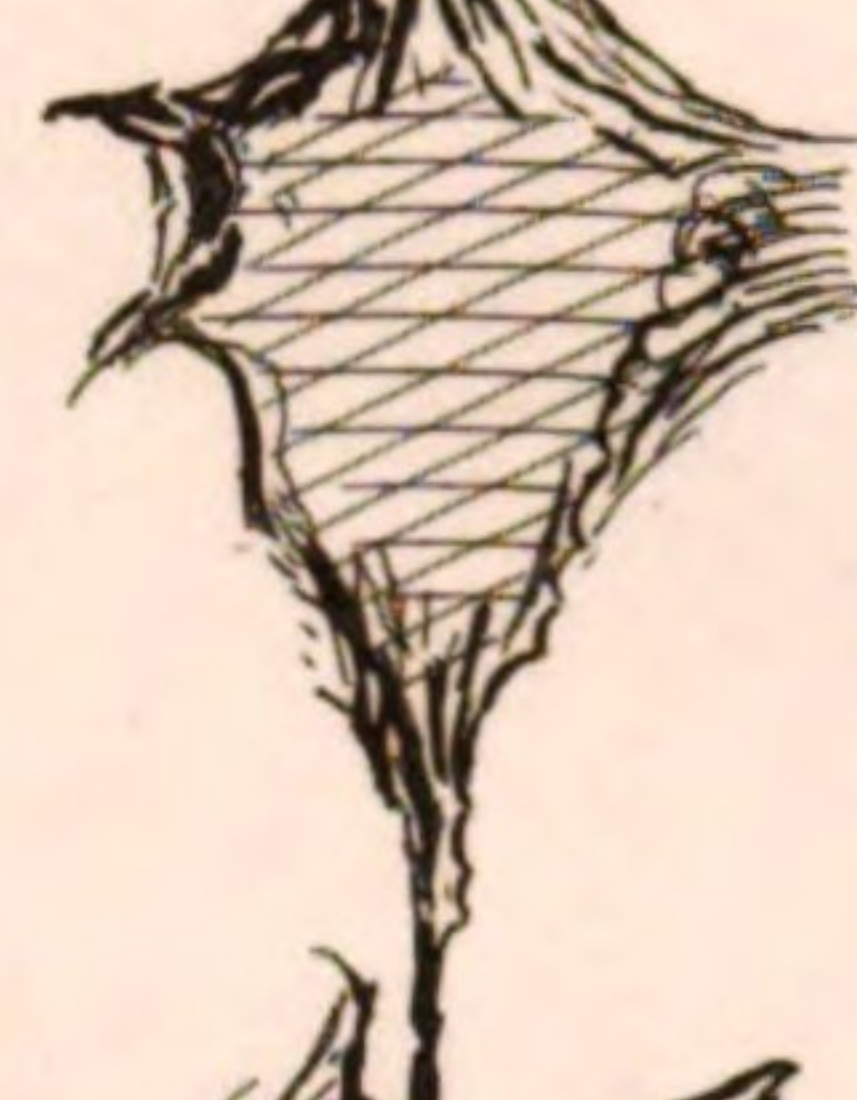
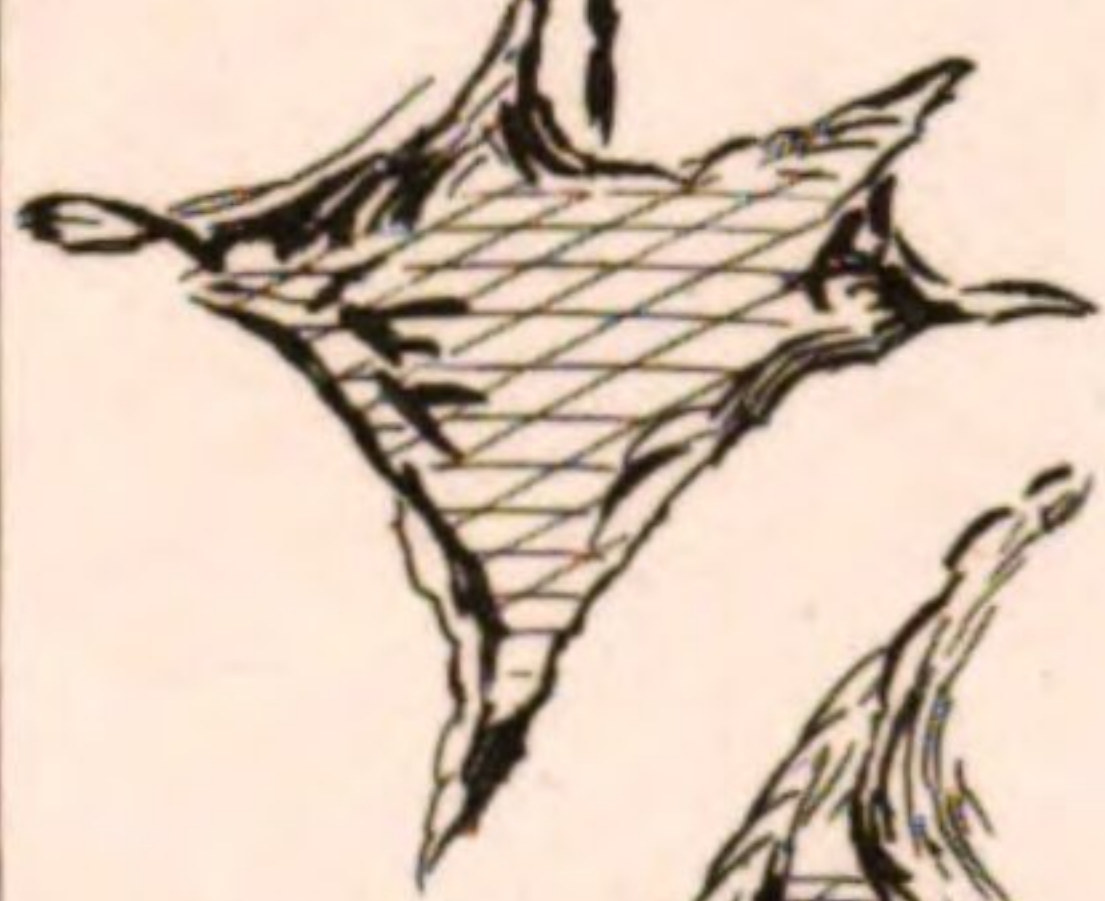
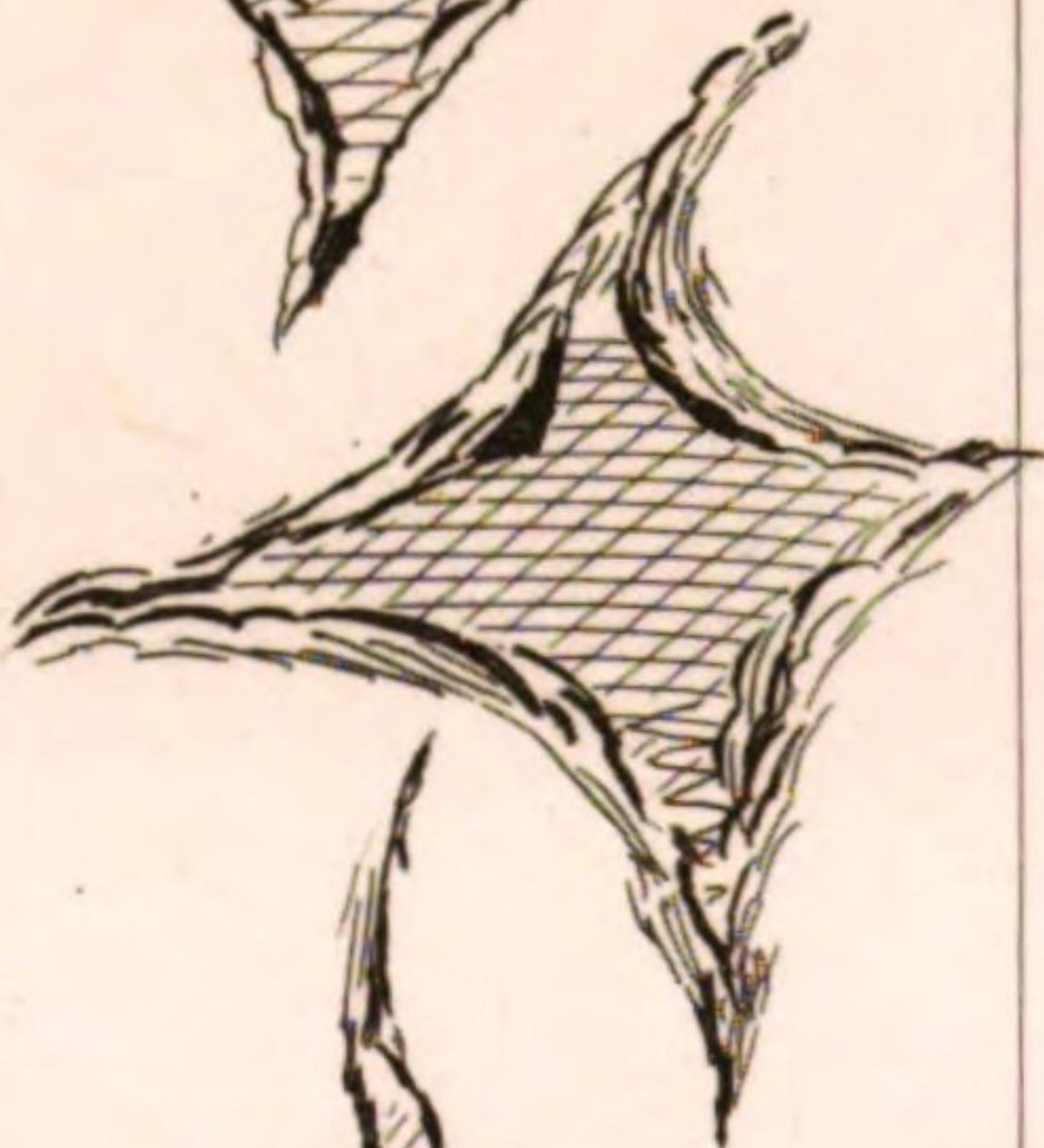
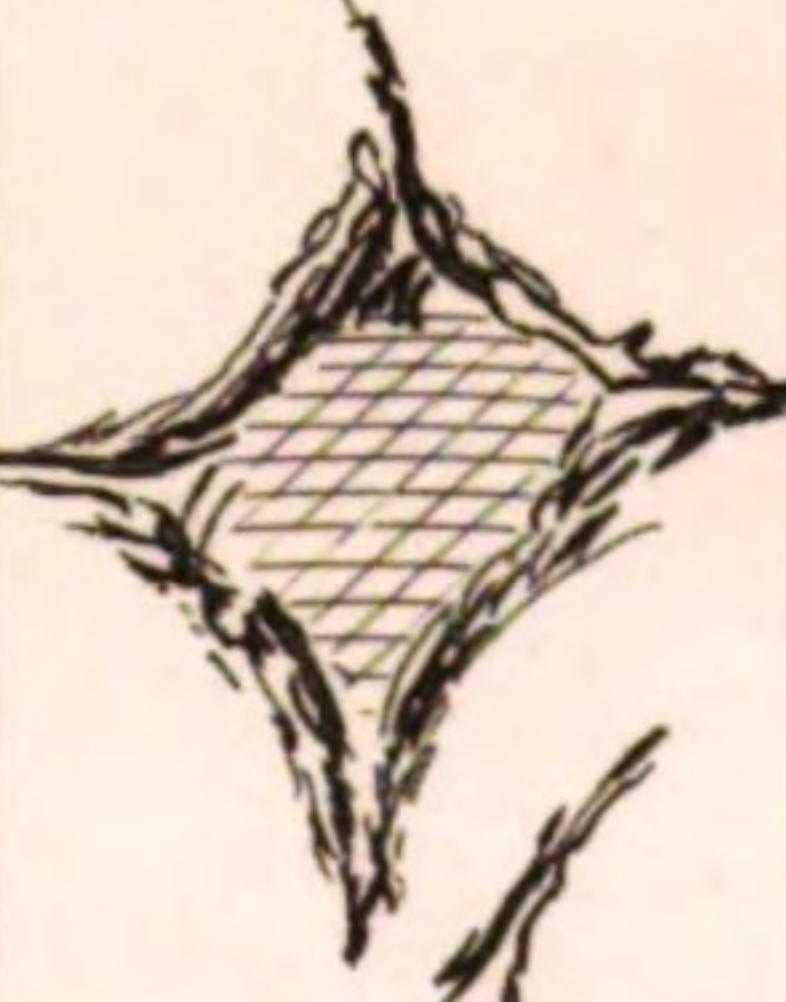
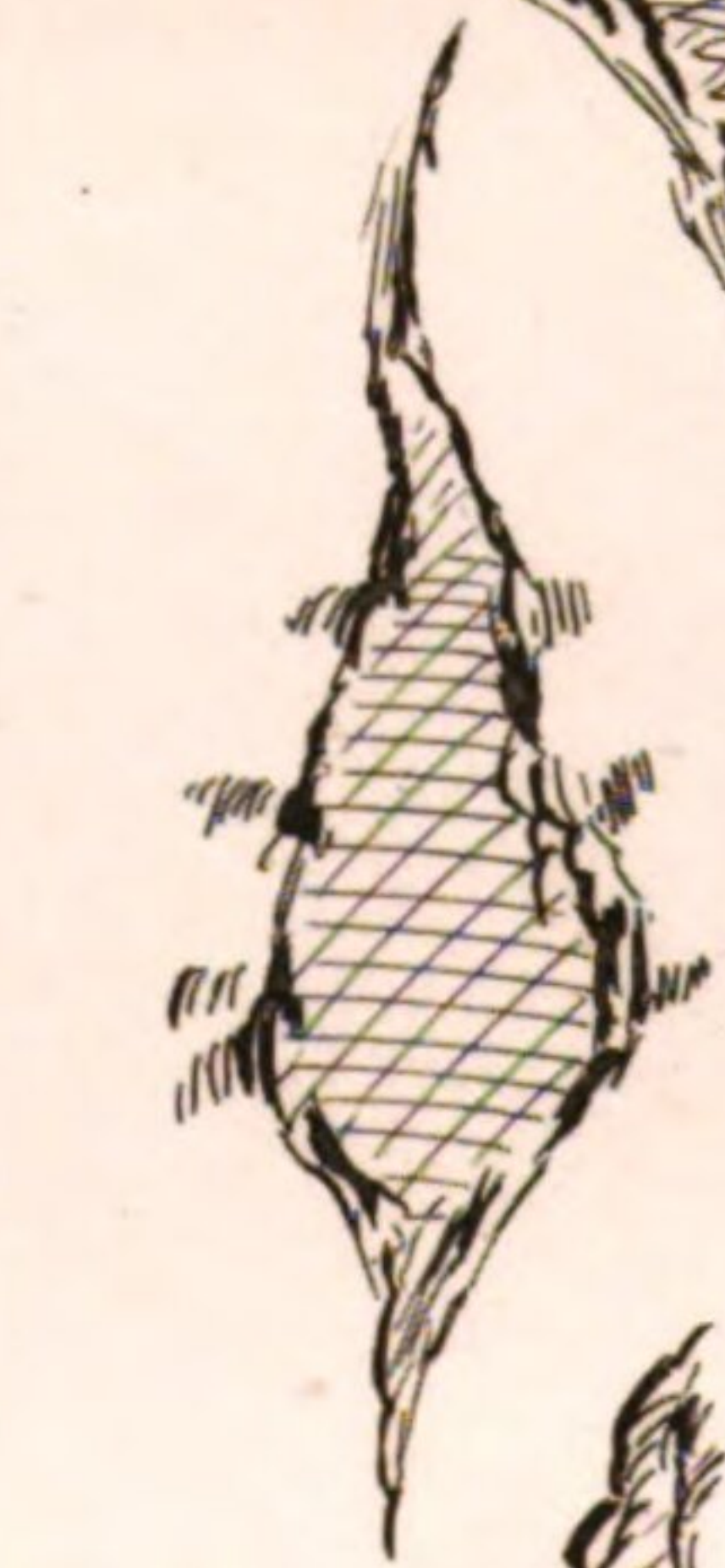
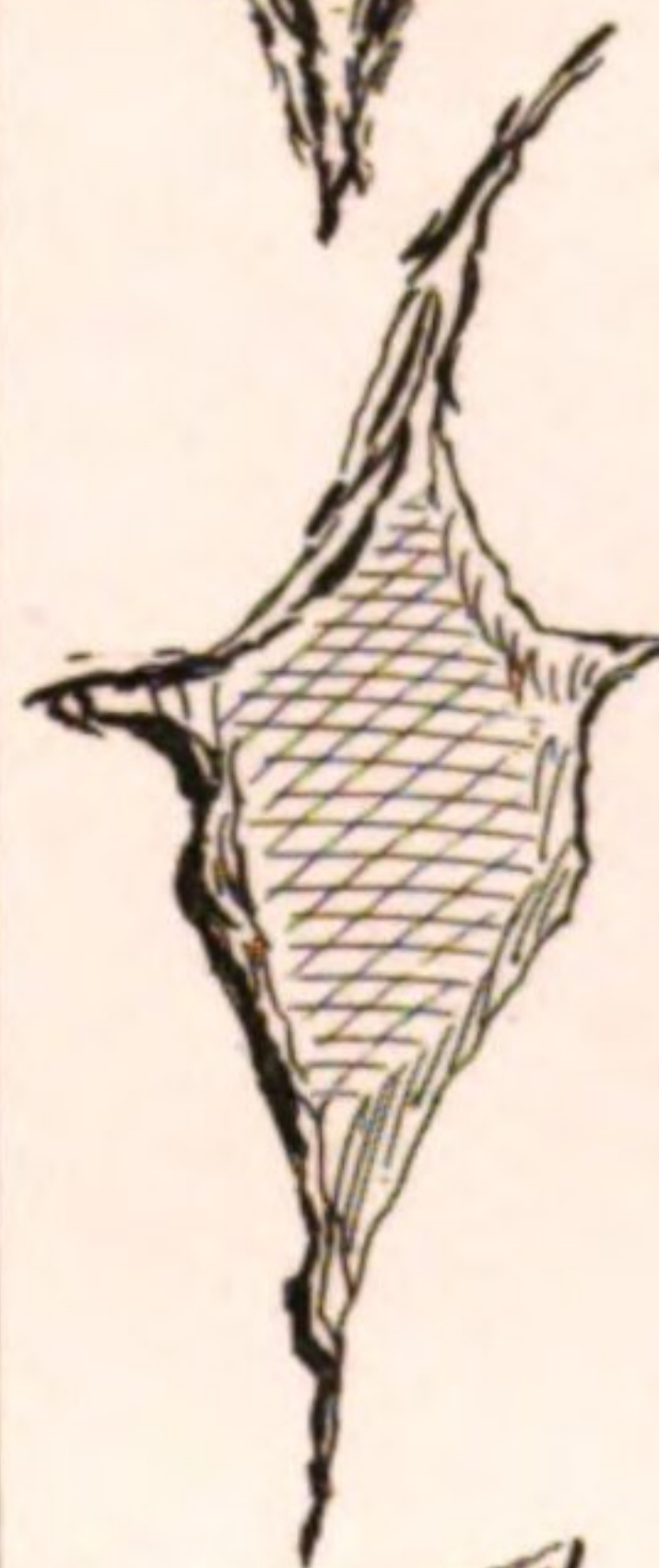
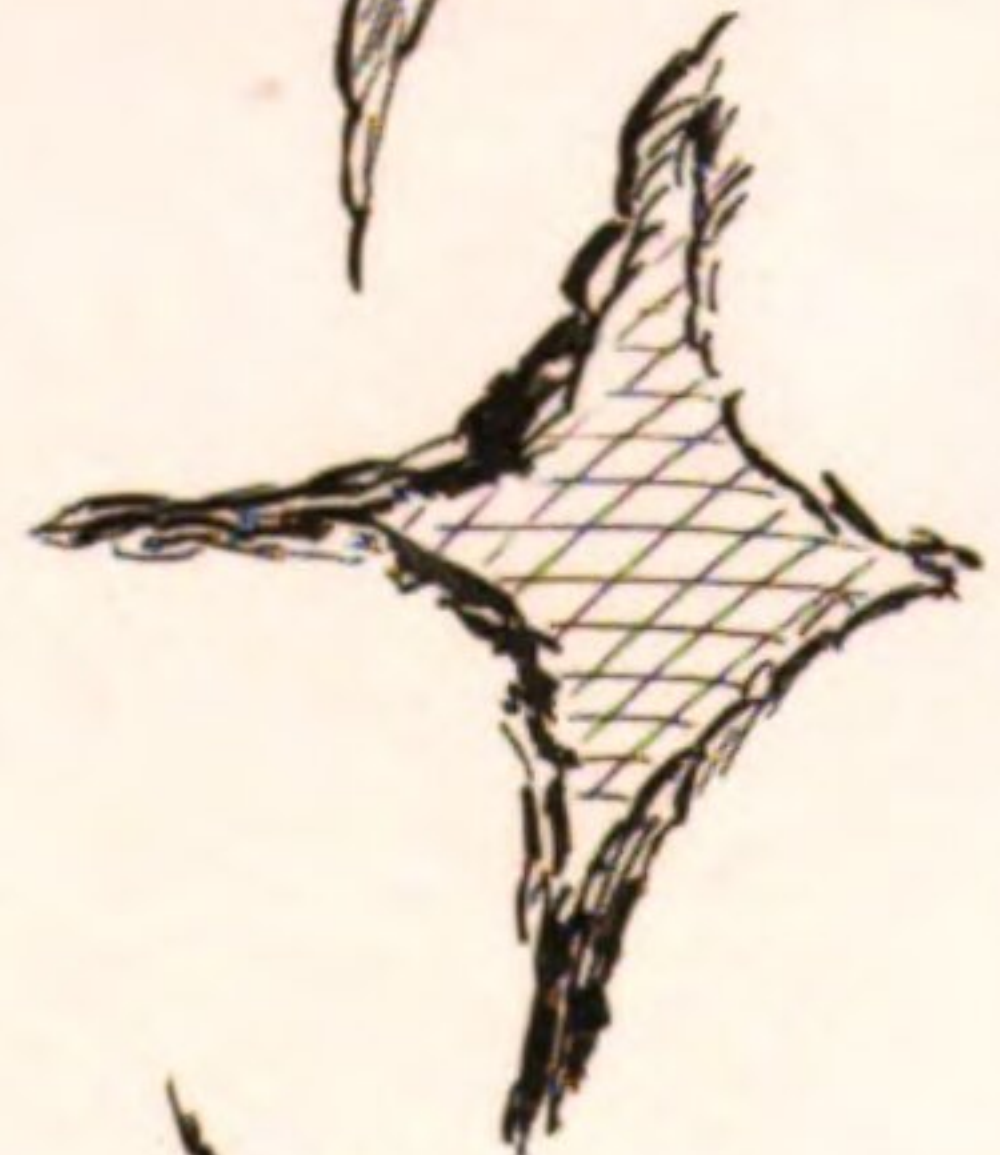
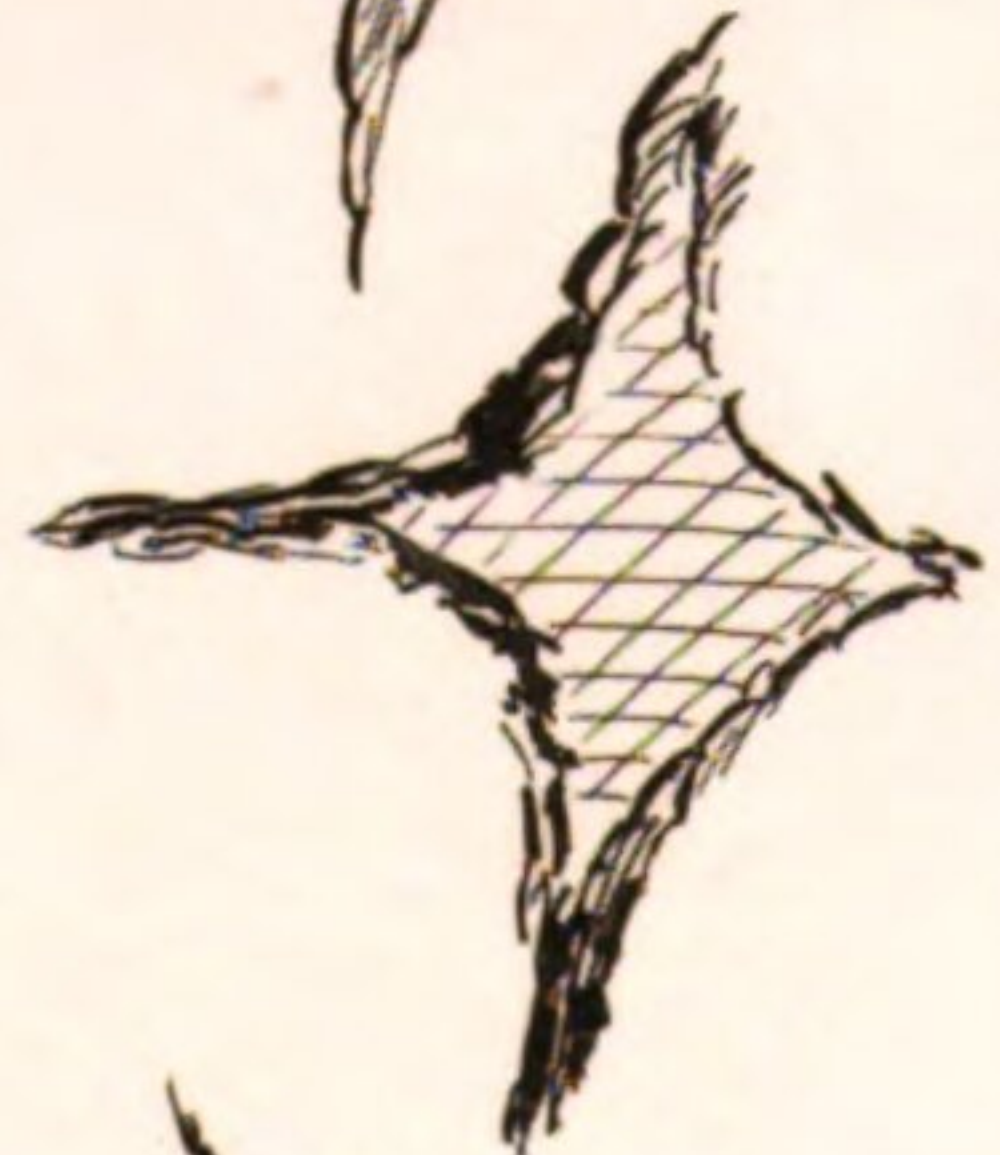
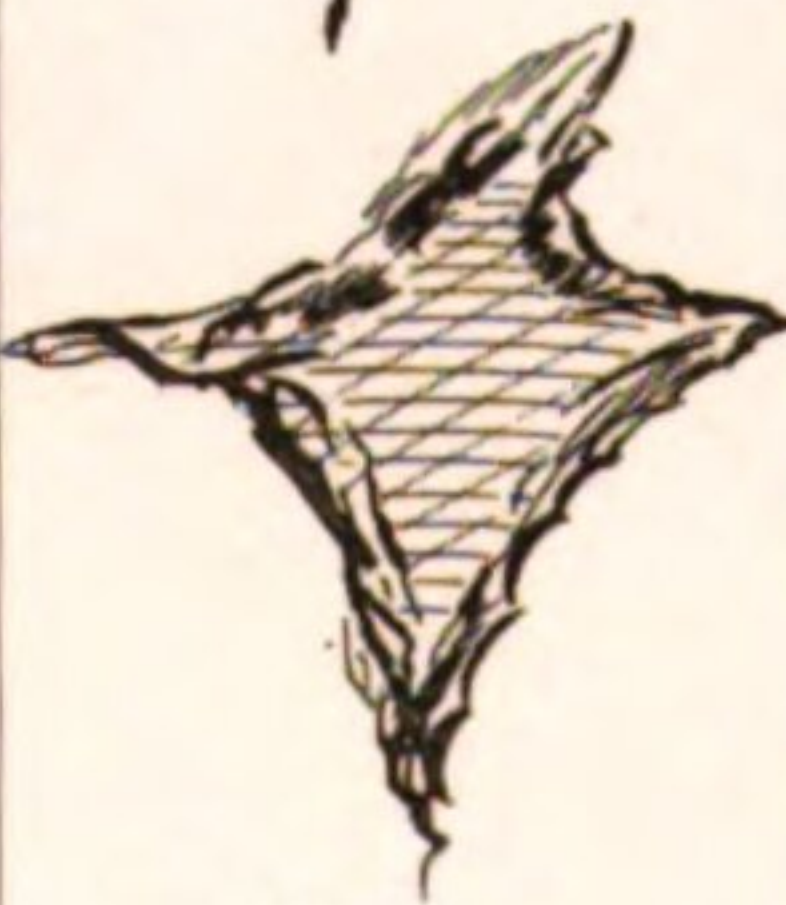
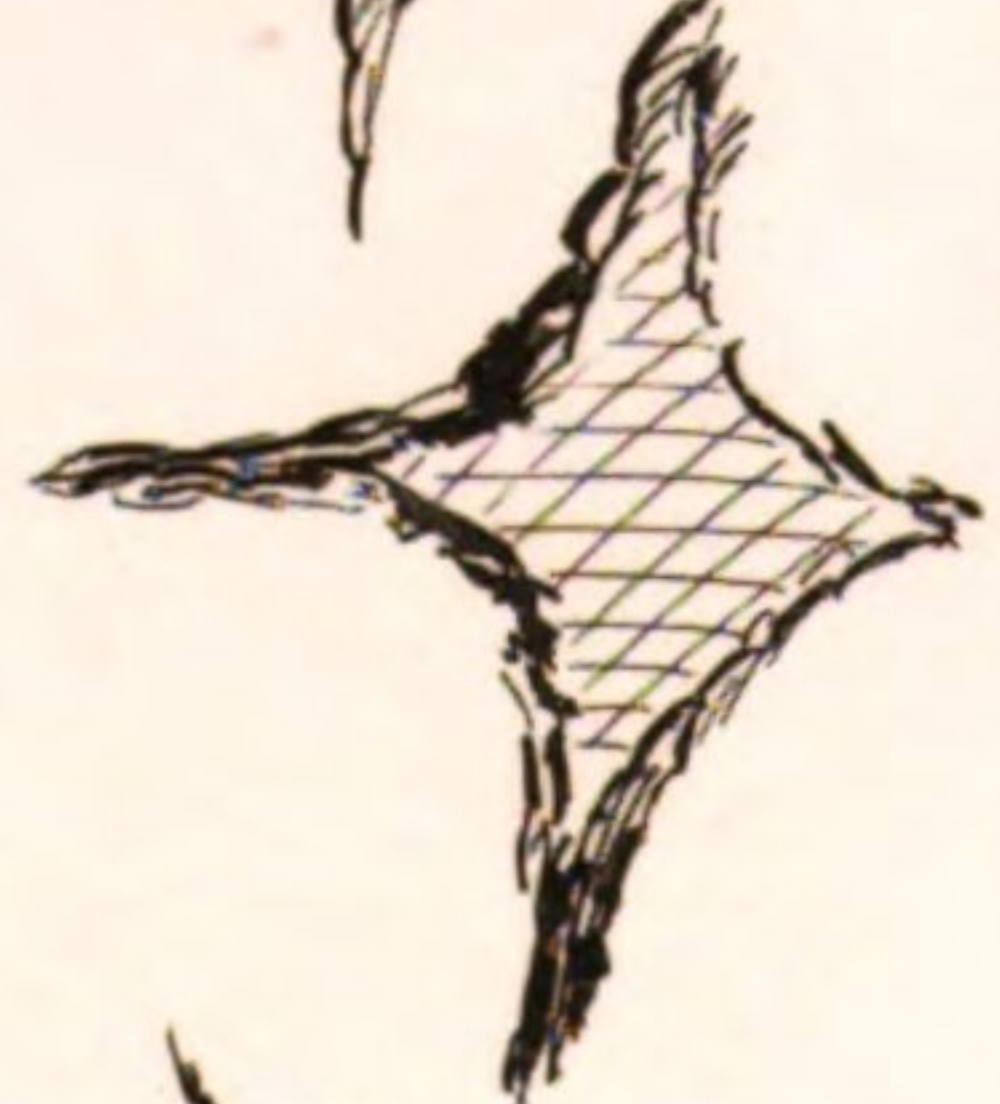
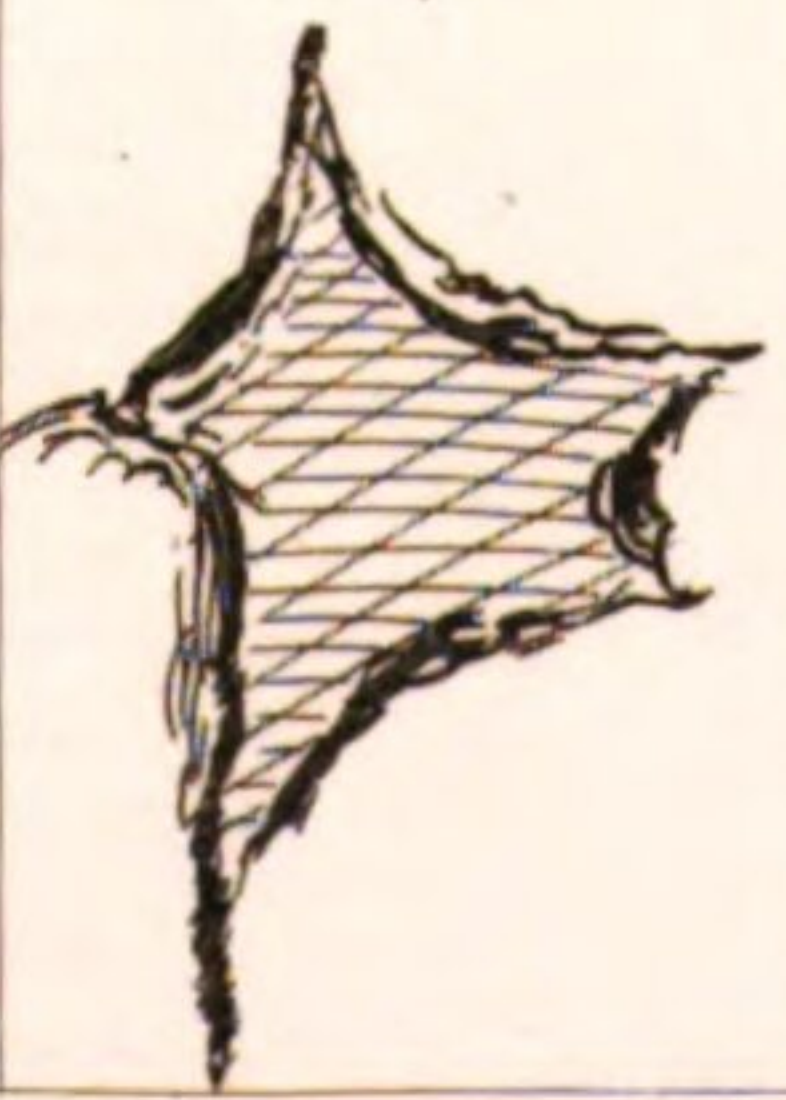
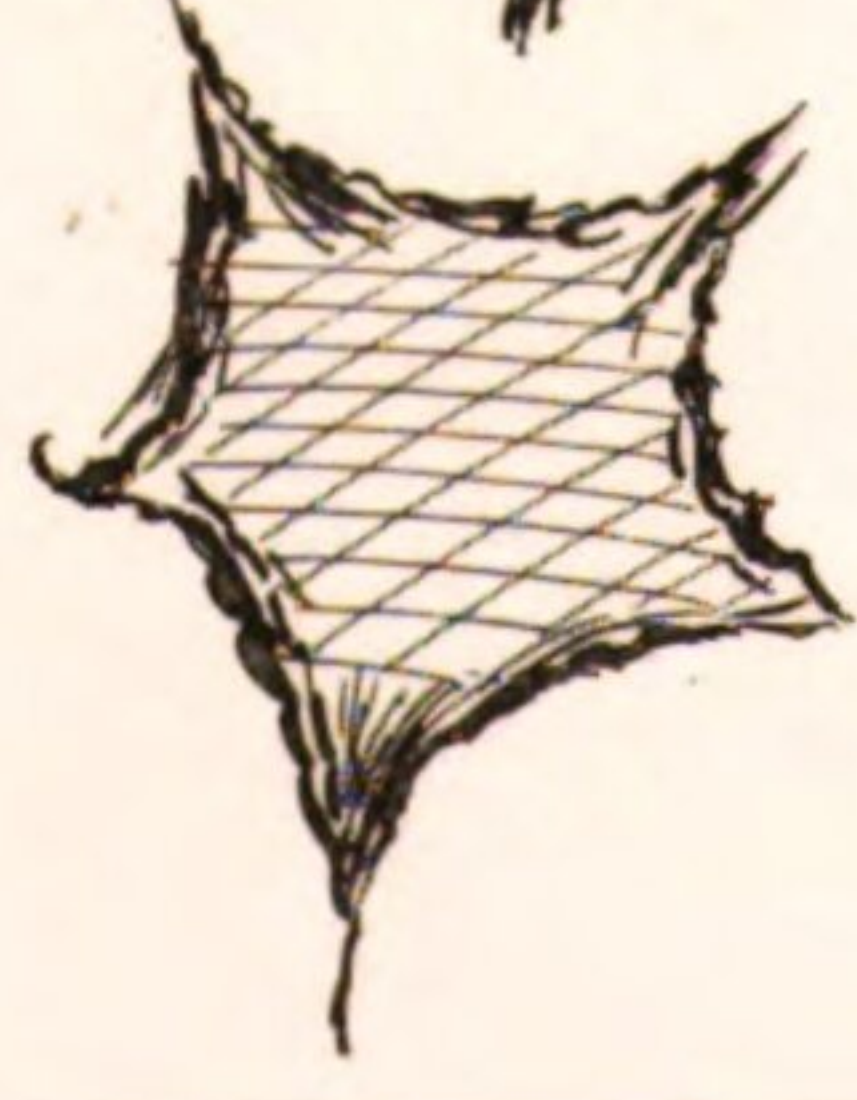
Table of Tensile Strength of Specimens taken from different parts of Guns which have been subjected to the Powder Proof, and burst in Experiments at Fort Monroe Arsenal, Va., during the years 1852 and 1853.

Number of Guns.	SPECIMENS—THE AXIS OF WHICH FORMS AN ANGLE OF 90° WITH THE AXIS OF THE GUN.										SPECIMENS—THE AXIS OF WHICH IS PARALLEL TO THE AXIS OF THE GUN.										MEAN RESULTS.		FORMER DETERMINATIONS.			
	FROM MUZZLE OF GUN.					FROM BETWEEN TRUNNIONS.					FROM BREECH.					FROM BETWEEN TRUNNIONS.					FROM BREECH.					
	Tensile force to a diameter of 0.95 inch.	Tensile force per square inch.	Specific gravity.	Tensile force to a diameter of 0.95 inch.	Tensile force per square inch.	Specific gravity.	Tensile force to a diameter of 0.95 inch.	Tensile force per square inch.	Specific gravity.	Tensile force to a diameter of 0.95 inch.	Tensile force per square inch.	Specific gravity.	Tensile force to a diameter of 0.95 inch.	Tensile force per square inch.	Specific gravity.	Tensile force to a diameter of 0.95 inch.	Tensile force per square inch.	Specific gravity.	Tensile force per square inch.	Specific gravity.						
24 pdrs.																										
1	16200	22855	7.1728	16700	23560	7.1651	16100	22714	7.1728	15200	21444	7.099	15600	22009	7.16	22516	7.1539	28208	7.18							
7	17900	25253	7.1611	17200	24266	7.1595	16600	23419	7.1497	17800	25112	7.1706	14600	20598	7.1148	23729	7.1511	22566	7.15							
173	14600	20598	7.1406	10000	14108	7.1322	14900	21021	7.1378	10000	14108	7.1263	16500	23278	7.1622	18622	7.1398	19040	7.14							
40	18700	26382	7.17	17000	23984	7.1627	16500	23278	7.1507	14000	19751	7.133	19700	27793	7.169	24237	7.157	29055	7.209							
163	15000	21162	7.11	13500	19046	7.0657	13100	18481	7.0606	14100	19892	7.0894	14900	21021	7.0945	19920	7.084	23272	7.15							
174	10200	14390	7.1309	11000	15519	7.1564	12000	16930	7.1598	10000	14108	7.1197	15200	21444	7.1598	16478	7.1453	14104	7.10							
193	19100	26947	7.1505	17500	24689	7.15	16100	22714	7.1458	19100	26946	7.1518	19200	27088	7.1600	25677	7.1516	28208	7.185							
287	17300	24407	7.0781	15000	21162	7.063	16800	23702	7.076	17100	24125	7.0728	17400	24548	7.0794	23588	7.0538	23836	7.147							
309	13800	19469	7.0488	14800	20880	7.067	14800	20880	7.0636	15000	21162	7.0777	14500	20457	7.052	20569	7.0618	{ 20028	7.08							
186	17500	24689	7.1444	19000	26805	7.162	18500	26100	7.156	14700	20739	7.1482	18700	26382	7.1578	24943	7.1536	{ 21453	6.996							
290	16100	22714	7.0722	15800	22291	7.0703	16700	23560	7.0857	16000	22573	7.0785	13500	19046	7.0633	22036	7.054	28067	7.185							
301	12800	18058	7.0536	14100	19892	7.0534	14300	20174	7.0574	12500	17635	7.0311	14100	19892	7.0562	19130	7.0503	{ 20874	7.085							
32 pdrs.																		{ 19897	6.967							
294	12000	16930	7.1424	14800	20480	7.1828	14800	20480	7.19	19000	26805	7.196	13300	18764	7.1596	20691	7.1741	22284	7.196							
324	11400	16083	7.0015	13000	18340	7.037	13500	19046	7.0364	13800	19469	7.039	14400	20316	7.0425	18650	7.0312	{ 19323	7.09							
325	11600	16365	7.003	12500	17635	7.0149	14100	19892	7.0235	12900	18199	7.0027	12500	17635	7.0129	17945	7.0114	{ 18815	6.96							
59	11000	15519	7.2009	11800	16647	7.25	11000	15519	7.2185	13900	19610	7.2774	16500	23278	7.284	18114	7.2462	{ 19464	7.024							
450	10900	15378	7.0834	10000	14108	7.0953	10000	14108	7.0917	11100	15660	7.1098	11700	16506	7.11	15152	7.098	20132	6.922							
20	15000	21162	7.199	11900	16789	7.185	14700	20739	7.1968	15200	21444	7.2215	18600	26241	7.24	21275	7.2084	22425	7.264							
Columbiads																		17348	7.108							
33	19000	26805	7.27	17100	24125	7.25	18400	25959	7.2826	18000	25395	7.253	20900	29486	7.296	26354	7.2703	22570	7.232							
1	24200	34142	7.296	22400	31602	7.27	23300	32872	7.33	23400	33013	7.31	23000	32449	7.27	32815	7.296	29252	7.317							
																		36000	7.312							

Interior Enlargements of Vents.

No. of Gun.	Calibre.	Tensile Strength.	Specific Gravity.	Rounds					Bore
				100	200	300	400	500	
101	24	29,062	7.209						 Bore 2 nd Class. No. 173
102	24	23,270	7.45						
103	24	14,390	7.40						
104	24	16,241	7.175						
105	24	10,425	7.185						
106	24	18,623	7.125						
107	24	16,241	7.175						
108	24	25,491	7.182						

Interior Enlargements of Vents.

N ^o of Gun.	Class of Gun.	Calibre.	Tensile Strength.	Specific Gravity.	Rounds.					
					100	200	300	400	500	800
40	1	24	29.062	7.209						24 pdr. 3rd Class. N^o 173 
163	2	24	23.275	7.15						
174	3	24	14.110	7.13						
193	1	24	26.241	7.175						
186	1	24	26.523	7.185						
290	2	24	23.413	7.123						
11	1	32	31.744	7.210						
63	2	32	23.131	7.145						

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FIRST REPORT
UPON THE
CHEMICAL ANALYSIS OF SPECIMENS
OF
CAST IRON GUN METAL.
PIKESVILLE ARSENAL.

1851.

FIRST REPORT

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CHEMICAL ANALYSIS OF SPECIMENS OF CAST IRON GUN METAL.
PIKESVILLE ARSENAL, 1851.

U. S. CHEMICAL LABORATORY,

Pikesville Arsenal, July, 1851.

SIR: The following report of operations in the chemical laboratory at this post, since its establishment in August, 1849, is respectfully submitted.

In pursuance of your letter, authorizing the institution of experiments "to determine the causes which so materially affect the quality of gun metal," the undersigned immediately commenced preparations for the duty which you were pleased to confide to them.

The requisite alteration of one of the workshops, to render it adapted to the purposes of a chemical laboratory, consumed several months, and the necessary importation of most of the apparatus (owing to the difficulty of procuring much of it in this country at reasonable prices, and some of it even at any cost) was the cause of so much additional delay, that analytic investigation could not be commenced until March, 1850. The operators, however, were actively engaged, during the interval, in superintending the construction of the apartments, and the purchase and arrangement of apparatus.

Our appointments were then complete; the limited amount appropriated specifically for these essays, having, by personal attention and proper outlay, been made to suffice for the erection and furnishing of a laboratory upon an improved plan, comprising every facility not only for the present investigations, but for any others that the Department may deem proper to institute.

It is, therefore, gratifying to know that our preparations for an extended course of duty, have not been more expensive than the usual cost of a limited and ordinary plan. Moreover, at the conclusion of our labors, we shall leave the laboratory unimpaired in its resources for any new purposes, and by a small annual appropriation, it may be continually maintained in serviceable condition.

As many parts of the processes heretofore followed, for the analysis of cast iron, proved insufficient upon examination and trial, to furnish satisfactory results, we deemed it indispensable to make a series of preliminary essays with a view of remedying their defects; and after several months' careful investigation matured a process which seemed to fulfil every requirement. Modifications were afterwards suggested by experience, which have shortened the time required for the analysis, and further experience will doubtless still more abridge it. Essential improvements have also been suggested since the completion of the analyses embraced in a following table.

The process followed in those analyses will be given in some detail, in order to demonstrate that every means was adopted to insure accuracy and completeness in the results, as far as our own knowledge combined with that of other chemists would allow. It was devised with a view to the qualitative and quantitative examination of each specimen, simultaneously, and is so systematically arranged, that any ingredient existing in gun-metal, even in minute proportion, cannot escape detection during the progress of manipulation. The almost constant occurrence of certain bodies, as constituents of gun-metal, rendered such a method practicable and effected great economy of time, for otherwise a determination of the *composition* of every sample must necessarily have preceded the quantitative estimation of each constituent, as all specimens are not precisely alike in the character and proportion of their constituents.

Chemical analytic processes, always tedious and time consuming, are especially so when purely of a scientific character and undertaken to obtain reliable data for important deductions, as the manipulations are often repeated for verification, and must be exact. Our results are of this nature, because our aim has been to make a complete, instead of a partial examination, of each specimen, since it is only by such minute investigations that we can determine hereafter what are the objectionable, the indifferent, or the beneficial ingredients of gun-metal. When the multiplication of analyses shall

have determined the unimportance of estimating certain components because of their indifferent influence, the search for them may then be omitted, and time be thus saved by shortening the process of analysis. Until then, however, the only secure mode of procedure is to make thorough examinations, as we have done. Notwithstanding the long time and nice treatment involved in the analysis of each specimen, we have been enabled by close and constant attention to present the composition of thirty-two specimens, selected as strong cases, which were determined between June 17, 1850, and the date of this report. The analyses originally made between the time of opening the Laboratory and June 17, 1850, were executed by those processes which experience afterwards proved not to be sufficiently exact, and were accordingly rejected, as not furnishing reliable results. These processes, however, as well as their results, together with ample notes on every operation performed or observed during the investigations are recorded in the "Record of Laboratory Operations," which is filed in the Laboratory, as part of its Archives.

Our present report is one of progress only, for although the results show many important and interesting facts, they are still too limited to permit many positive deductions. Our final report will give the results of additional analyses, from a comparison of which, with those embraced in the present report, we hope to establish fixed rules in relation to the qualities of cast iron, based upon carefully determined data.

As it is the policy of Government to prepare for war in time of peace, the inquiry into what may constitute the safest materials for the manufacture of its military arms, is one of the most important that can be undertaken. It is the basis of security to the officers and troops employing them, against damage from bursting and other casualties arising from imperfections, while it enables them with the more confidence and certainty to secure the defeat of their adversaries.

While the invaluable results obtained by your energy and perseverance during your recent investigations into the quality of gun-metal, as presented partially in your published Reports to the Chief of Ordnance, of 1846 and 1847, and more fully detailed in your complete manuscript record not yet published, have already proved of the highest value to the service in the classification of the cannon at the several Forts and Arsenals, we trust that the chemical researches now in progress will, conjointly with your extended

observation and experience, still further extend our knowledge of the material employed for the fabrication of cannon, so as to enable us to control its quality.

For the sake of comparison between the mechanical properties and chemical composition of gun-metal, we present a general table of those specimens which we have analyzed, and append the results of your experience as furnished by you from your manuscript record.

Specific Gravity and Tenacity determined by Capt. L. A. B. Walbach, Ordnance Corps, U. S. A. Chemical Composition determined by Campbell Morfit and James C. Booth.

Calibre.	Num-ber.	Date.	Initials of inspector.	Foundry.	Weight of gun in pounds.	Specific gravity.	Tenacity per square inch.	Class.	CHEMICAL CONSTITUENTS.							Sodium and Potassium.	Cobalt and Nickel.
									Sulphur.	Phosphorus.	Arsenic.	Manganese.	Calcium.	Aluminum.			
42 pdr.	17	1842	R. L. B.	West Point	8438	7.227	28631	1	.00340	.02200	trace	.09220	.00490	.01440	.0022	—	—
"	18	1842	R. L. B.	"	8450	7.020	18758	3	.00340	.05090	—	.07570	.00360	.03460	.0040	trace	—
32 pdr.	307	1834	W. J. W.	"	7589	7.185	25105	1	.00193	.01333	trace	.13844	trace	.00071	.0013	—	—
"	* 322	1839	J. W. R.	"	7512	7.090	24823	3	.00074	.01111	—	.11681	.00423	trace	.0009	—	—
"	* 325	1839	J. W. R.	"	7450	7.124	19464	3	—	.04400	trace	.05985	.00362	.00214	.0017	—	—
"	10	1841	W. M.	"	6989	7.245	31734	1	—	.03511	trace	.06634	trace	.00143	trace	—	—
24 pdr. ^a	119	1827	J. B.	"	5846	7.220	26799	1	.00320	.02530	—	.09160	.00610	.00280	trace	—	—
"	† 301	1838	J. W. R.	"	5502	7.085	20874	3	.00041	.02700	—	.03600	.00400	.00140	trace	—	—
42 pdr.	27	1837	J. W. R.	Columbia	8624	7.210	31311	1	.00120	.02110	—	.02134	.00610	.00430	.0060	trace	—
"	28	1837	J. W. R.	"	8625	7.220	31734	1	.00162	.02178	—	.12547	.00302	trace	.0013	—	—
"	† 54	1839	J. W. R.	"	8641	7.040	18335	3	—	.04000	—	.13120	.00370	.00430	.0110	—	—
"	† 56	1839	J. W. R.	"	8636	7.080	18335	3	.00339	.00622	—	.11248	.00483	trace	.01598	—	—
8 in. S. C.	6	1840	J. W. R.	"	5880	7.150	19605	3	—	lost	trace	.06057	.00306	.00214	trace	—	—
32 pdr.	239	1833	W. J. W.	"	7532	7.240	21156	3	—	.01911	trace	.06561	.00242	.00290	trace	—	—
"	248	1833	W. J. W.	"	7610	7.190	26516	1	.00014	.02178	—	.12763	.00302	—	.0013	—	—
"	131	1831	J. B.	"	5574	7.220	26657	2	—	.02444	trace	.08364	—	.00357	—	—	—
24 pdr.	344	—	W. J. W.	Bellona	—	7.200	29619	1	—	.02598	trace	.10672	.00242	—	trace	—	—
32 pdr.	364	—	W. J. W.	"	—	7.080	20874	3	.00140	.06950	—	.15700	.00730	.02130	trace	—	—
"	366	—	W. J. W.	"	—	7.110	20028	3	—	.03689	—	.10383	.00242	.00289	trace	—	—
"	7	1832	J. B.	Fort Pitt	7461	7.14	23131	2	.00179	.02000	—	.12763	trace	.00086	.0022	—	—
"	9	1832	J. B.	"	7396	7.13	22284	2	.00190	.02330	trace	.10890	.00300	.00360	trace	—	—
"	10	1832	J. B.	"	7405	7.23	29196	1	.00430	.02220	—	.18030	trace	.0050	.00160	trace	—
"	12	1832	J. B.	"	7413	7.22	31029	1	trace	.02589	trace	.10888	trace	.00214	trace	—	—
"	20	1832	W. J. W.	"	7385	7.17	26939	1	trace	.03644	trace	.13412	trace	trace	trace	—	—
"	21	1832	W. J. W.	"	7425	7.08	22425	3	.00244	.04178	—	.13195	.00121	.00714	.0036	—	—
"	42	1833	W. J. W.	"	7395	7.09	22425	3	.00248	.03290	—	.15791	trace	—	.0013	—	—
"	44	1833	W. J. W.	"	7383	7.17	27362	1	.00310	.02220	trace	.11680	trace	.01140	.0011	—	—
"	45	1833	W. J. W.	"	7456	7.17	28490	1	.00400	.02350	trace	.09220	.00420	.00430	trace	—	—
"	46	1833	W. J. W.	"	7433	7.08	21579	3	.00220	.02440	—	.10240	trace	.00290	trace	—	—
"	47	1833	W. J. W.	"	7430	7.14	25105	2	.00250	.02040	—	.10300	trace	.00290	trace	.0027	—
"	48	1833	W. J. W.	"	7452	7.14	26657	2	—	.06178	—	.10880	—	—	.0023	—	—
"	† 225	1839	J. W. R.	"	7534	7.06	13399	3	.00210	.01950	trace	.09520	trace	.00640	trace	—	—

* Hot-Blast Iron, see page 334.

† Supposed to be Hot-Blast Iron.

^a No. 119 selected for Siege train in place of No. 301, rejected.

NOTE.—Columns of Iron, Combined Carbon, Graphite, Silicon, and Slag, reported blank in the original, and therefore omitted here.

In the preceding table we have omitted the graphite, carbon, slag, and silicium, because the results which we have obtained are not uniformly reliable; and yet the researches of other chemists, confirmed by our own, have proved that their accurate determination is of the highest importance in respect to the quality of gun-metal. While a following table shows a very satisfactory average, there are irreconcilable discrepancies in individual samples. These arise from the (advancing but) scarcely perfected state of chemical analysis, as applied to the complicated character of cast iron. We have surmounted many of the difficulties in the analytic separation of the foreign ingredients of gun-metal; and by still continuing their studious investigation, desire to render the plan of analysis more simple and accurate. We have already, by careful examination, ascertained that the various methods heretofore employed for estimating carbon, are too uncertain in their results, and have devised new processes, which will be in every way satisfactory.

The determination of the silicious matter being necessarily connected with that of the carbons, it was incumbent upon us, to review the methods employed for estimating it. We have been engaged in these researches for the last three months, and with more especial reference to silica during the last month, and are surprised to discover that the processes generally adopted for ascertaining the ratio of silicium, combined with the metal, to that of slag, which is an accidental ingredient, are not at all accurate. They are incorrect in principle, and must consequently yield erroneous results. For upon examining the same specimen repeatedly, under identical circumstances, the proportion of the two states of silica was found to vary. In pursuing these researches we hope to devise a new method which will afford uniformly correct results.

Guided by these considerations, we have preferred giving, for the present, general average results, which, as is shown by the annexed table, are fully confirmatory of your Classification of the guns based upon their physical properties, as carefully determined by you and recorded in your several reports to the Ordnance Department. These latter are not affected by the want of uniform accuracy in the details consequent upon imperfect methods of analysis. It being otherwise with our results, we desire and intend to redetermine both the carbonaceous and silicious constituents of gun-metal before completing our table.

We believe that it would not be advisable to lay our yet incomplete results before the public, until they can be published with that degree of confidence in their reliability, which the great importance of the subject demands.

TABLE II.—Average Results of Analyses of Gun Metal. Influence of Single Ingredients.

Classes.	MECHANICAL TESTS.		CHEMICAL CONSTITUENTS.						
	Specific gravity.	Tensile strength.	Combined Carbon.	Graphite.	Silicium.	Slag.	Phosphorus.	Sulphur.	Earthy metals.
1	7.204	28865	.0977	.0507	.0417	.0215	.0239	.0017	.0117
2	7.140	24767	.0819	.0576	.0538	.0200	.0300	.0021	.0094
3	7.088	20176	.0726	.0560	.0531	.0219	.0321	.0021	.0144

TABLE III.—Influence of two or more Ingredients.

Classes.	Specific gravity.	Tensile strength.	Silicium and Carbon.	Silicium and Slag.	Graphite and Slag.	Graphite, Slag, and Silicium.	Graphite, slag, Silicium, and Phosphorus.	Total Carbon.
1	7.204	28865	.1394	.0632	.0722	.1139	.1378	.1484
2	7.140	24767	.1357	.0738	.0776	.1314	.1614	.1395
3	7.088	20176	.1257	.0750	.0780	.1311	.1632	.1286

An inspection of the first of the foregoing tables, representing the average amount of each foreign ingredient in gun-metal, deduced from all the analyses, although not exact from causes already stated, shows a considerable difference in the proportions of those ingredients in each of the three Classes into which you have divided the guns. It will be observed that while the proportion of Combined carbon diminishes from the 1st. to the 3d. Class, that of Silicium similarly increases, so that their united amounts are nearly the same. In other words, it appears that Silicium can replace the Carbon to a certain extent; but that the quality of the metal is injured where the amount of Silicium approaches that of the Carbon. Karsten made a similar observation in determining the limit between cast iron and steel, but did not notice the influence of that substitution.

But the differences become more striking by combining the ingredients, variously together, as in the second of the tables; and especially by comparing the extremes, which are each derived from a larger number of obser-

vations than the mean, and are consequently less influenced by an occasional error in the detailed results.

After showing the total amount of Carbon (both combined and uncombined) we have thrown Silicium and Combined Carbon together, which indicates the replacement by silicium of that portion of carbon set free in the form of graphite. The column of Silicium and Slag shows the general depreciation of the metal as the silicious matter increases. The remaining columns exhibit, in an increasing degree, the influence of the foreign associates of gun-metal. The column of Earthy metals embraces the metallic bases of alumina, lime, and magnesia, potassa and soda; but so very minute was their total amount—averaging from $\frac{2}{10}$ to $\frac{3}{10}$ of one per cent. of the metal—and so variable were the different samples as exhibited by the general table of analyses, that we comprised them together in a single column.

When the more exact determination of both carbonaceous and silicious matters shall have been completed, we do not doubt that the differences noted above will be exhibited in still more striking numbers; for the tables indicate the important bearing which those substances have, each in two different states, upon the character of gun-metal.

TABLE IV.—Average Results of Hot and Cold Blast Iron.

Blast.	Specific gravity.	Tensile strength.	Combined Carbon.	Graphite.	Silicium.	Slag.	Phosphorus.	Sulphur.	Manganese.
Cold blast	7.194	26859	.0836	.0476	.0386	.0189	.0228	.0014	.1141
Hot blast	7.074	18993	.0687	.0600	.0593	.0375	.0185	.0010	.0960

Continued.

Blast.	Earths.	Silicium and Carbon.	Silicium and Slag.	Graphite and Slag.	Graphite, Slag, and Silicium.	Graphite, Slag, Silicium, and Phosphorus.	Total Carbon.	Graphite, Slag, Silicium, Phosphorus, Sulphur, and Earths.
Cold blast	.0117	.1219	.0575	.0665	.1051	.1280	.1312	.1411
Hot blast	.0146	.1281	.0938	.0975	.1568	.1753	.1287	.1909

The above table comprising the averages of all the hot blast metal, and of all the cold blast examined, except the few peculiar samples, Nos. 42,

to 48, exhibit in a marked degree the influence of the hot blast. Although the Carbon decreases in the hot blast about 0.3 per cent. of the metal, and the total amount of Carbon and Graphite is nearly the same in both metals, yet the quantity of Silicium replacing Carbon increases in a greater ratio, so that the total amount of Carbon and Silicium is greater by 0.12 per cent. in the hot than in the cold blast. The augmenting reduction of the Earthy bodies to the metallic state is shown by that column, as well as by the column of Slag—which must, in part, at least, be formed by the reoxidation of these metals during the refining of the iron by remelting.

The summation of the ingredients, likely to affect the quality of metal, shows an increase of one per cent. There can be no doubt that a more precise determination of the carbonaceous and silicious ingredients will exhibit the diversity in a stronger light.

Respectfully submitted by

CAMPBELL MORFIT,

Analytical Chemist.

JAMES C. BOOTH,

Consulting Chemist.

To CAPT. L. A. B. WALBACH,

On Foundry Service, Ordnance Corps, U. S. Army.

U. S. CHEMICAL LABORATORY,
Pikesville Arsenal, Md., Oct. 18, 1851.

CAPT. L. A. B. WALBACH,
U. S. A. of Ordnance—on Foundry Service.

DEAR SIR: I respectfully present for your examination, some results obtained, since the report, by our new method for estimating graphite. The uniformity of the proportional relation of graphite to tensile strength, throughout the specimens, proves the accuracy of this process, and the results rectify the average of graphite as given in our report, and make it as follows:—

1st. Class		100
2d. “		113
3d. “		143

When all the specimens have been examined, the differences between each Class may be a little altered, but enough has been done to know that the *proportion* will not be altered. Below is a list of the specimens which have been examined.

TABLE V.

Specimens.	Graphite.	Tensile strength.	Specimens.	Graphite.	Tensile strength.
No. 307, W. P.	.120	25105	No. 48, F. P. F.	.1225	26657
No. 119, W. P.	.115	26799	No. 322, W. P.	.1325	24823
No. 27, C. F.	.0725	31311	No. 325, W. P.	.140	19464
No. 248, C. F.	.105	26516	No. 301, W. P.	.150	20874
No. 18, W. P.	.140	18758	No. 54, C. F.	.160	18335
No. 20, F. P. F.	.1075	26939	No. 56, C. F.	.160	18335
No. 44, F. P. F.	.095	27362	S. C. 8 in. C. F.	.140	19605
No. 131, C. F.	.105	26657	No. 366, B. F.	.140	20028
No. 7, F. P. F.	.120	23131	No. 42, F. P. F.	.145	22425
No. 9, F. P. F.	.115	22284	No. 225, F. P. F.	.1625	13399

Yours, respectfully,
CAMPBELL MORFIT.

SECOND REPORT

UPON THE

CHEMICAL ANALYSIS OF SPECIMENS

OF

CAST IRON GUN METAL.

PIKESVILLE ARSENAL.

1852.

SECOND REPORT

UPON THE

CHEMICAL ANALYSIS OF SPECIMENS OF CAST IRON GUN METAL.
PIKESVILLE ARSENAL, 1852.

U. S. CHEMICAL LABORATORY,

Pikesville Arsenal, August, 8, 1852.

SIR: We respectfully submit herewith, a statement of the operations in the Chemical Laboratory, at this Post, since our first report of July, 1851.

The progress of our labors has confirmed the conviction which we therein expressed, that the results then presented, together with the processes by which they were obtained, although as perfect as the state of chemical knowledge would at that time permit, are not entirely reliable. It has also enabled us to adopt many improvements for attaining to correct data; so that now, we are enabled to report a systematic and exact method of investigation, with the complete analysis of eight samples, and partial results from twenty-four more, which are in a forward state of completion.

In these and similar cases, investigations are necessarily slow, by reason of the carefulness and precision with which every step is made. The same course has frequently to be retraced, as well to satisfy the inquirer that there is no error, as to ascertain if there is no better path leading to the same object.

The published experience of numerous laborers in the same field has been consulted, their processes duly considered, and their doubts investigated; but we have, in all instances, preferred relying upon our own elaborations.

There will appear, in our report, many conclusions at variance with

those of other chemists, upon the same questions; but, we believe, that they will, after examining our formulæ of proceeding, be satisfied that the results are those necessarily attendant upon analyses, conducted with the care and minuteness which we have endeavored to apply to this subject.

The several samples confided to us for examination, have been, in every instance, treated in the qualitative as well as quantitative manner, in one and the same assay, so that there was no reasonable possibility that any property in the metal could pass unobserved. In this way, every specimen is presented in the accompanying report, with a complete description of all its constituents, and every single analysis is, in all particulars, a true representative of the sample of which it treats.

Having cleared away the difficulties which lay in our path, our future progress will be much more rapid than heretofore.

TABLE I.—*Examination of Cast Iron Gun Metal, by Campbell Morfit and James C. Booth. One gramme of metal.*

Number of specimens.	Specific gravity.	Tensile strength.	Iron.	Allotropic Carbon.	Combined Carbon.	Silicium.	Slag.	Sulphur.	Phosphorus.	Ar-senic.	Manganese.	Magnesium.	Calcium.	Aluminum.	Sodium and Potassium.	Cobalt and Nickel.	Total.
No. 17, W. P. F., 42 pdr.	7.227	28631	—	.0220	.0240	.00720	.0002	.00070	—	trace	—	.00098	.00028	—	.00044	—	—
No. 307, W. P. F., 32 pdr.	7.185	25105	—	.0240	.0170	.00753	.0005	.00040	.0109	trace	—	trace	.00014	—	.00026	—	—
*No. 10, W. P. F., 32 pdr.	7.245	31734	.905400	.0200	.0220	.00776	.0025	—	.0130	trace	.0150	trace	.00028	.00410	trace	—	.98794
No. 119, W. P. F., 24 pdr.	7.220	26799	.919180	.0230	.0195	.00650	.0020	.00065	.0130	—	.0109	.00120	.00057	.00300	trace	—	.99960
No. 27, C. F., 42 pdr.	7.210	31311	—	.0145	.0255	.00329	.0010	.00024	—	—	—	.00120	.00086	—	.00120	—	—
No. 28, C. F., 42 pdr.	7.220	31734	.918400	.0220	.0170	.00329	.0000	.00033	.1031	—	.0167	.00060	trace	.00535	trace	—	.99677
No. 248, C. F., 32 pdr.	7.190	26516	—	.0210	.0140	.00588	.0005	.00003	—	—	—	.00060	—	—	.00026	—	—
No. 344, B. F., 32 pdr.	7.200	29619	—	.0250	.0160	.00520	.0010	—	—	trace	—	trace	—	—	trace	—	—
No. 10, F. P. F., 32 pdr.	7.230	29196	—	.0185	.0135	.01435	.0020	.00086	—	—	—	trace	.00100	—	trace	trace	—
No. 12, F. P. F., 32 pdr.	7.220	31029	—	.0180	.0150	.01410	.0025	—	—	trace	—	trace	.00043	—	trace	trace	—
No. 20, F. P. F., 32 pdr.	7.170	26939	.924900	.0215	.0095	.01000	.0035	—	.0131	trace	.0083	trace	trace	.00450	—	—	.99530
No. 44, F. P. F., 32 pdr.	7.170	27362	—	.0190	.0205	.01310	.0020	.00059	—	trace	—	trace	.00230	—	.00030	—	—
No. 45, F. P. F., 32 pdr.	7.170	28490	—	.0195	.0185	.01310	.0030	.00080	—	trace	—	.00060	.00086	—	trace	—	—
1st. Class—Average	7.204	28805	—	.02061	.01784	.008561	.00159	.00051	—	—	—	.00086	.00075	—	.00049	—	—
No. 131, C. F., 24 pdr.	7.220	26657	.923300	.0210	.0230	.00675	.0005	—	.0123	trace	.0070	—	.00070	.00450	—	—	.99907
No. 7, F. P. F., 32 pdr.	7.140	23131	—	.0240	.0210	.00520	.0025	.00036	—	—	—	trace	.00017	—	.00043	—	—
No. 9, F. P. F., 32 pdr.	7.130	22284	—	.0230	.0040	.01435	.0015	.00040	—	trace	—	.00060	.00070	—	trace	—	—
No. 47, F. P. F., 32 pdr.	7.140	25105	—	.0225	.0145	.01180	.0007	.00050	—	—	—	trace	.00060	—	.00054	—	—
No. 48, F. P. F., 32 pdr.	7.140	26657	—	.0245	.0105	.01480	.0015	—	—	—	—	—	—	—	.00045	—	—
2d. Class—Average	7.154	24767	—	.0230	.0146	.01058	.00134	.00042	—	—	—	.00060	.00054	—	.00047	—	—
No. 18, W. P. F., 42 pdr.	7.020	18758	—	.0280	.0030	.01170	.0020	.00070	—	—	—	.00070	.00030	—	.00080	trace	—
No. 322, W. P. F., 32 pdr.	7.090	24823	—	.0265	.0120	.01740	.0020	.00015	—	—	—	.00084	trace	—	.00020	—	—
*No. 325, W. P. F., 32 pdr.	7.024	19464	—	.0280	.0020	.02000	.0040	—	—	—	—	.00072	.00043	—	.00034	—	—
*No. 301, W. P. F., 24 pdr.	7.085	20874	.924000	.0300	.0120	.01790	.0020	.00008	.0153	—	.0070	.00080	.00028	.00600	trace	trace	1.01536
No. 54, C. F., 42 pdr.	7.040	18335	—	.0320	.0070	.01130	.0010	—	—	—	—	.00074	.00086	—	.00220	—	—
No. 56, C. F., 42 pdr.	7.080	18335	—	.0320	.0080	.01080	.0010	.00067	—	—	—	.00096	trace	—	.00026	—	—
No. 6, C. F., 8 in. S. C.	7.150	19605	—	.0275	.0135	.00700	.0020	—	—	trace	—	.00062	.00043	—	trace	—	—
No. 239, C. F., 32 pdr.	7.240	21156	.929000	.0255	.0185	.00440	.0045	—	.0123	trace	.0066	.00048	.00058	.00160	trace	—	1.00346
No. 364, B. F., 32 pdr.	7.080	20874	—	.0245	.0085	.00650	.0010	.00030	—	—	—	.00140	.00042	—	.00010	—	—
No. 366, B. F., 32 pdr.	7.110	20028	.925400	.0280	.0015	.00730	.0020	—	.0161	—	.0083	.00061	.00057	.00450	trace	—	.99428
No. 21, F. P. F., 32 pdr.	7.080	22425	—	.0265	.0000	.01020	.0005	.00049	—	—	—	.00024	.00143	—	.00070	—	—
No. 42, F. P. F., 32 pdr.	7.090	22425	—	.0290	.0090	.00960	.0020	.00050	—	—	—	trace	—	—	.00026	—	—
No. 46, F. P. F., 32 pdr.	7.080	21579	—	.0270	.0070	.00980	.0010	.00046	—	—	—	trace	.00060	—	trace	trace	—
No. 225, F. P. F., 32 pdr.	7.060	13399	—	.0325	.0045	.00820	.0115	.00044	—	trace	—	trace	—	—	trace	—	—
3d. Class—Average	7.087	20148	—	.0283	.0082	.01086	.0026	.00042	—	—	—	.00074	.00059	—	.00061	—	—

* No. 10 endured the extreme proof. No. 325 burst at 112th. Service round. No. 301 burst at 208th. Service round.

The preceding table presents the results as far as obtained, and it will be observed that the whole of the first series of analyses, is nearly completed.

The specific gravity and tensile strength determinations, which it comprises, are those recorded in your manuscript Report to the Ordnance Department, and for which we acknowledge our indebtedness.

The proportion of "TOTAL CARBON" seems to prove nothing in regard to its influence upon the quality of the metal, although this may yet appear to be otherwise, upon further examination and more critical consideration of the results. There is, however, a decided relation of the Carbons, in their separate states, to specific gravity and tensile strength, both by average, and in individual cases, as the following table will show. At first sight, there would appear to be a few discrepant examples, but the gradation of the results is so generally uniform, we are certain that in such cases a reference to your notes upon the specimens will show some just cause which will reconcile them.

The results, therefore, strongly sustain your Classification, for while the ALLOTROPIC CARBON increases in the *Third Class* guns, the COMBINED CARBON decreases, and *vice versa* in those of the *First Class*. The extremes of the amount of Carbons, as affecting the increase or diminution of the excellence of the quality of the metals, their influence upon its molecular construction, and the possibility of their being replaced by some other ingredient, are matters of great importance and still under consideration.

TABLE II.

	Number of specimens.	Specific gravity.	Tensile strength.	Total Carbon.	Combined Carbon.	Allotropic Carbon.
1st. Class.	No. 17, W. P. F., 42 pdr.	7.227	28631	.0460	.0240	.0220
	No. 307, W. P. F., 32 pdr.	7.185	25105	.0410	.0170	.0240
	No. 10, W. P. F., 32 pdr.	7.245	31734	.0420	.0220	.0200
	No. 119, W. P. F., 32 pdr.	7.220	26799	.0425	.0195	.0230
	No. 27, C. F., 42 pdr.	7.210	31311	.0400	.0255	.0145
	No. 28, C. F., 42 pdr.	7.220	31734	.0390	.0170	.0220
	No. 248, C. F., 32 pdr.	7.190	26516	.0350	.0140	.0210
	No. 344, B. F., 32 pdr.	7.200	29619	.0410	.0160	.0250
	No. 10, F. P. F., 32 pdr.	7.230	29196	.0320	.0135	.0185
	No. 12, F. P. F., 32 pdr.	7.220	31029	.0330	.0150	.0180
2nd. Class.	No. 20, F. P. F., 32 pdr.	7.170	26939	.0310	.0095	.0215
	No. 44, F. P. F., 32 pdr.	7.170	27362	.0395	.0205	.0190
	No. 45, F. P. F., 32 pdr.	7.170	28490	.0380	.0185	.0195
	No. 131, C. F., 24 pdr.	7.220	26657	.0440	.0230	.0210
	No. 7, F. P. F., 32 pdr.	7.140	23131	.0450	.0210	.0240
	No. 9, F. P. F., 32 pdr.	7.130	22284	.0270	.0040	.0230
	No. 47, F. P. F., 32 pdr.	7.140	25105	.0370	.0145	.0225
	No. 48, F. P. F., 32 pdr.	7.140	26657	.0350	.0105	.0245
	No. 18, W. P. F., 42 pdr.	7.020	18758	.0310	.0030	.0280
	No. 323, W. P. F., 32 pdr.	7.090	24823	.0385	.0120	.0265
3rd. Class.	No. 325, W. P. F., 32 pdr.	7.024	19464	.0300	.0020	.0280
	No. 301, W. P. F., 24 pdr.	7.085	20874	.0420	.0120	.0300
	No. 54, C. F., 42 pdr.	7.040	18335	.0390	.0070	.0320
	No. 56, C. F., 42 pdr.	7.080	18335	.0400	.0080	.0320
	No. 6, C. F., S. C. H.	7.150	19605	.0410	.0135	.0275
	No. 239, C. F., 32 pdr.	7.240	21156	.0440	.0185	.0255
	No. 364, B. F., 32 pdr.	7.080	20874	.0330	.0085	.0245
	No. 366, B. F., 32 pdr.	7.110	20028	.0295	.0015	.0280
	No. 21, F. P. F., 32 pdr.	7.080	22425	.0260	—	.0265
	No. 42, F. P. F., 32 pdr.	7.090	22425	.0380	.0090	.0290
<i>Averages.</i>						
First Class guns . . .		7.204	28805	.0384	.0178	.0206
Second Class guns . . .		7.154	24767	.0376	.0146	.0230
Third Class guns . . .		7.087	20148	.0365	.0082	.0283

The different effects produced by the "*hot and cold blast*," are clearly exhibited in the following table, both in reference to chemical composition, and, as you have previously shown, to specific gravity and tensile strength.

TABLE III.

Blast.	Number.	Specific gravity.	Tensile strength.	Total Carbon.	Allotropic Carbon.	Combined Carbon.	Silicium	Silicium and Combined Carbon.	Silicium and Total Carbon.	Slag.	Slag and Allotropic Carbon.
Cold Blast	No. 17	7.227	28631	.0460	.0220	.0240	.00720	.03120	.0532	.0002	.0222
	No. 307	7.185	25105	.0410	.0240	.0170	.00753	.02453	.0485	.0005	.0245
	No. 10	7.245	31734	.0420	.0200	.0220	.00776	.02976	.0497	.0025	.0225
	No. 119	7.220	26799	.0425	.0230	.0195	.00650	.02600	.0490	.0020	.0250
	No. 27	7.210	31311	.0400	.0145	.0255	.00329	.02879	.0433	.0010	.0155
	No. 28	7.220	31734	.0390	.0220	.0170	.00329	.02029	.0423	—	.0220
Hot Blast	No. 322	7.090	24823	.0385	.0265	.0120	.01740	.02940	.0559	.0020	.0285
	No. 325	7.024	19464	.0300	.0280	.0020	.02000	.02200	.0500	.0040	.0320
	No. 301	7.085	20874	.0420	.0300	.0120	.01790	.02990	.0599	.0020	.0320
	No. 225	7.060	13399	.0370	.0325	.0045	.00820	.01270	.0452	.0115	.0440

Averages.

Blast.	Specific gravity.	Tensile strength.	Total Carbon.	Allotropic Carbon.	Combined Carbon.	Silicium.	Silicium and Combined Carbon.	Silicium and Total Carbon.	Slag.	Slag and Allotropic Carbon.
Hot	7.065	19640	.0369	.0292	.0076	.0159	.0235	.0528	.00487	.0341
Cold	7.218	29219	.0407	.0209	.0208	.0059	.0267	.0476	.00124	.0221

It will be observed, that while there is a *very great* disproportion in the quantities of each *single* ingredient in the hot and cold blast metal, yet there is nearly the same amounts of several combined; such as the total amount of Carbon, the amount of Silicium and Combined Carbon, or Silicium and the Total Carbon. These numbers are significant. For although there is not a great disparity between the amounts of "TOTAL CARBON" produced by hot or cold blast, yet the hot blast has evidently driven off a portion of Carbon from combination, so that the cold blast metal contains two and three-fourth times as much Combined Carbon. The hot blast metal, however, meets with some compensation for this loss of carbon, by reducing by its intense heat, a larger amount of silica and assuming Silicium.

The quantity of Silicium taken up by the hot blast is two and seven-tenths times greater than by the cold blast, and hence the joint amount of Silicium and Combined Carbon, in the hot and cold blasts, is very nearly

equal. Since the amount of Allotropic Carbon is less disproportional in both blasts, the joint amount of Silicium and Total Carbon is likewise nearly the same.

A wide difference is observable between the amounts of Slag in the two metals; the hot blast containing nearly four times as much as the cold blast. If these metals have been made by remelting and keeping in fusion the common furnace "pig," it is evident that the hot blast "pig" must have contained a very large amount of Silicium, because in this refined metal it still retains 2.7 times as much Silicium as the cold blast, and nearly four times as much Slag, arising from the oxidation of the Silicium formerly in the "pig."

The Slag and Allotropic Carbon being of a brittle nature, and not united with the iron, coat the crystalline plates of metal and diminish their surface of contact; and, consequently, it follows that the tensile strength of the metal must decrease partly in proportion to the increase of Slag and Allotropic Carbon.

This injurious effect is most remarkably exhibited in No. 225, F. P. F., as compared with all others; for while the amount of its Slag, or Slag and Allotropic Carbon, is twice as great as the average of the cold blast metal, or five times as great as the average of your Third Class guns, its tensile strength is reduced to the very low number of 13399.

But by a comparison of all the results together, it is evident that the loss of strength in the metal is likewise due, in part, to the replacement of Carbon by Silicium; and hence we may refer to this fact and to the increase of Carbon, as the chief causes of the diminution of tensile strength.

We cannot, at present, draw inferences from each single case, in the above comparative table of *hot* and *cold* blast metal, because several of the constituents still remain to be determined; and until their presence and quantity are known, their influence cannot even be conjectured. Among these ingredients are, Phosphorus, Aluminum, and Manganese, the quantities of which have been estimated in only a few specimens. When their presence and quantity shall have been ascertained in the *whole series* of samples, we shall be better enabled to determine their influence, by comparison; and it is probable, that these seeming anomalies in regard to the other constituents will disappear, and the peculiar mechanical behavior of the metal, be shown to be due to its chemical constitution.

The advance in these labors has been quite as much as we anticipated. Your own observation has enabled you to appreciate the incessant application of the investigators, and the great variety of experiments, essays, and methods, pursued to reach the desired end; and although the history of them is here condensed in a few pages, the practical details consumed many weary months, and embraced much perseverance, study, and research.

Until the whole course of investigation has been traversed, we shall not pretend to comprise all that is to appear in relation to it; nor do we wish to draw hasty conclusions liable to subsequent retraction.

We, therefore, prefer awaiting the entire completion of the series, when, we doubt not, valuable deductions will be arrived at, which will amply compensate us for our unwearied labors, and the government for its liberal expenditure.

Respectfully submitted by

CAMPBELL MORFIT,

Analytical Chemist.

JAMES C. BOOTH,

Consulting Chemist.

TO CAPT. L. A. B. WALBACH,

On Foundry Service, Ordnance Corps, U. S. Army.

The advance in these labors has been quite as much as we anticipated. Your own observation has enabled you to appreciate the incessant application of the investigator, and the great variety of experiments, essays, and methods, pursued to reach the desired end; and although the history of them is here condensed in a few pages, the practical details concerned many weary months, and embraced much perseverance, study, and reflection. And the whole course of investigation has been directed, we shall not pretend to overstate all that is to appear in relation to it; but the way to draw hasty conclusions, and to draw hasty conclusions, when we doubt not valuable deductions will be arrived at, which will amply compensate us for our unwearied labors, and the government for its liberal expenditure.

FINAL REPORT

UPON THE

CHEMICAL ANALYSIS OF SPECIMENS

OF

CAST IRON GUN METAL.

PIKESVILLE ARSENAL.

1855.

FINAL REPORT,

UPON THE

CHEMICAL ANALYSIS OF SPECIMENS OF CAST IRON GUN-METAL.
PIKESVILLE ARSENAL, 1855.

July 27, 1855.

TO COL. BENJAMIN HUGER, U. S. A.,

Ordinance Officer on Foundry Service.

SIR: Having completed the chemical examination of certain specimens of cast iron gun-metal, commenced under the authority of your predecessor, the late Captain L. A. B. Walbach, U. S. A., we herewith respectfully present a final report of our operations, with a table of the results which we have obtained.

The long interval since our last report of progress, renders it proper that we should make some explanation of the delay. This was owing to the suspension of our operations, then in an active state of forwardness, by the sudden death of Capt. Walbach, and which, on account of private engagements, were not resumed until within a few months; since which time, they have been energetically carried on, and brought to a conclusion. And, in this connection, we cannot forego the pleasure of expressing our high appreciation of the character of the lamented deceased, and our sincere regret at his most untimely end. Learned and able upon this subject, with an unflagging interest in the investigation, he was always observant and ever prompt to acknowledge the difficulties of our labors; and his reflective mind enabled him, as we advanced in the work, to foresee the importance of a more extended field of research, embracing a chemical inquiry into the composition of all the elements used in the manufacture of gun-metal, from the raw material to the finished product. It was a cherished object of his

life, to evolve the invaluable knowledge to which such an investigation would lead; and although Providence has removed him in the midst of his bright and useful career, we trust that this plan may yet have a full realization.

In devising a method for the analysis of cast iron, many unanticipated difficulties were encountered; but, by persevering study and experiment, we were enabled to surmount the most of them, and to develop the process mentioned in our last report of progress; and which we now narrate in full, with the remark that further experience will doubtless render it more perfect and speedy. We have also been careful to revise the appended Table of Results; and, in filling up the blanks of the previous Table, have introduced a few corrections, clerical, and otherwise.

Upon a comparison of this Table with those heretofore presented during the progress of our researches, it will be observed that the columns giving the specific gravity and tensile strength have been omitted. We deemed it proper to make this omission, because such mechanical results are not strictly in the line of our examination; and for the reason also, that our ignorance of the circumstances under which they were obtained, makes us less confident of their exactness than we would be in that of our own determinations.

Moreover, the figures obtained by us, from a few samples, are discordant with those in the former tables. We are not aware how these errors may have occurred, but that they do exist is a sufficient motive for our rejection of *all* the results; for where a few are wrong, all may justly be suspected. We, therefore, recall the inferences which we drew in our last report; and, for the same reason, decline making any in the present instance. Such deductions, to be serviceable, must be from an accumulation of exact data, derived from a greatly extended series of analysis, not solely confined to the gun-metal itself, but comprising the ore, flux, and fuel, employed in its manufacture, together with the incidental products solid and gaseous.

Apart from the errors above mentioned, the limited extent of our investigation prevents, at present, the establishment of any laws as to the relation of chemical composition and physical structure, in gun-metal. The question is, therefore, still open as to the extent of availability, and reliability, of mechanical tests of its quality.

Advancement in any pursuit widens the field of vision, and gives more comprehensive views of the subject. Though at first largely appreciating the extent of our labors, the completion of them sensibly diminishes that esti-

mate of their usefulness; because we now see, that their end is only the beginning of an investigation, which must be greatly extended and minutely elaborated, in order to be productive of substantial utility. Time and industry only are necessary for a multiplication of analyses upon the plan before proposed, and these conjoined with exact mechanical tests, would doubtless solve the whole mystery of the chemical and physical relations of cast iron, and lead to the discovery of a process by which the metal may be invariably made in its best condition.

The research would be valueless applied to a single specimen, and should, therefore, embrace a large number to be similarly examined from their origin, in order to an extensive comparison whence to draw deductions; the only sure means of evolving truth in practical subjects. Thus we would learn the individual action of the several ingredients and materials existing in the ore, and materials employed in its reduction, and be enabled to control the causes which injuriously affect its quality.

The strongest argument in favor of such an investigation is its own importance and prospective advantages; for the manufacture of iron is the basis and index of modern civilization, and every effort tending to improve it is a matter of general welfare.

Economy is a small consideration as compared with the objects to be obtained; and as the undertaking is beyond private means, the Government should be the purse-bearer, since it has such a direct interest, from the results, in the perfection of its own armament.

Chemical Examination of Cast Iron Gun Metal, by Campbell Morfit and James C. Booth.

Number of Specimen.	Iron.	Graphitic Carbon.	Combined Carbon.	Silicium.	Slag.	Sulphur.	Phosphorus.	Ar-senic.	Manganese.	Calcium.	Aluminum.	Sodium and Potassium.	Cobalt and Nickel.	Total.
No. 17, W. P. F., 42 pdr.	.92400	.02200	.02400	.00720	.00020	—	.00489	trace	.02317	.00098	.00158	.00044	—	1.00874
No. 307, W. P. F., 32 pdr.	.93520	.02400	.01700	.00753	.00050	.00013	.00533	trace	.02462	trace	trace	.00026	—	1.01471
*No. 10, W. P. F., 32 pdr.	.93520	.02000	.02200	.00776	.00250	—	.00036	trace	.02100	trace	.00106	trace	—	1.01016
No. 119, W. P. F., 24 pdr.	.91918	.02300	.01950	.00650	.00200	.00026	.00510	—	.01448	.00120	.00170	trace	—	.99349
No. 27, C. F., 42 pdr.	.93520	.01450	.02550	.00329	.00100	—	.00444	—	.02820	.00120	.00158	.00120	—	1.01697
No. 28, C. F., 42 pdr.	.91840	.02200	.01700	.00329	trace	—	.00436	—	.03547	.00060	.00280	trace	—	1.00390
No. 248, C. F., 32 pdr.	.92610	.02100	.01400	.00588	.00050	—	.00800	—	.02317	.00060	.00106	.00026	—	1.00057
No. 344, B. F., 32 pdr.	.90650	.02500	.01600	.00520	.00100	—	.00978	trace	.03774	trace	.00106	trace	—	1.00228
No. 10, F. P. F., 32 pdr.	.92750	.01850	.01350	.01435	.00200	.00091	.00666	—	.01521	trace	—	trace	trace	.99963
No. 12, F. P. F., 32 pdr.	.90790	.01800	.01500	.01410	.00250	—	.00480	trace	.03258	trace	.00264	trace	trace	.99795
No. 20, F. P. F., 32 pdr.	.92490	.02150	.00950	.01000	.00350	.00039	.00721	trace	.02027	trace	—	—	—	.99727
No. 44, F. P. F., 32 pdr.	.94150	.01900	.02050	.01310	.00200	.00026	.00311	trace	.00800	.00230	.00212	.00030	—	1.01219
No. 45, F. P. F., 32 pdr.	.92400	.01950	.01850	.01310	.00300	.00033	.00577	trace	.01882	.00060	.00106	trace	—	.99554
No. 131, C. F., 24 pdr.	.92330	.02100	.02300	.00675	.00050	.00039	.00489	trace	.00724	.00070	.00106	—	—	.98883
No. 7, F. P. F., 32 pdr.	.92890	.02400	.02100	.00520	.00250	—	.00800	—	.01955	trace	—	.00043	—	1.00975
No. 9, F. P. F., 32 pdr.	.90650	.02300	.00400	.01435	.00150	—	.00800	trace	.02244	.00060	.00106	trace	—	.98155
No. 47, F. P. F., 32 pdr.	.91840	.02250	.01450	.01180	.00070	.00039	.01290	—	.00941	trace	.00424	.00054	—	.99698
No. 48, F. P. F., 32 pdr.	.92540	.02450	.01050	.01480	.00150	—	.00666	—	.01665	—	.00158	.00045	—	1.00204
No. 18, W. P. F., 42 pdr.	?	.02800	.00300	.01170	.00200	.00070	.01018	—	?	.00070	.00030	.00080	trace	—
No. 322, W. P. F., 32 pdr.	.90335	.02650	.01200	.01740	.00200	—	.00844	—	.03548	.00084	.00158	.00020	—	1.00774
*No. 325, W. P. F., 32 pdr.	.88480	.02800	.00200	.02000	.00400	—	.00666	—	.05212	.00072	trace	.00034	—	.99907
*No. 301, W. P. F., 24 pdr.	.92400	.03000	.01200	.01790	.00200	—	.00626	—	.02244	.00080	.00234	trace	—	1.01802
No. 54, C. F., 42 pdr.	.92155	.03200	.00700	.01130	.00100	.00013	.00800	—	.01448	.00074	.00316	.00220	—	1.00242
No. 56, C. F., 42 pdr.	.93170	.03200	.00800	.01080	.00100	.00039	.00755	—	.01303	.00096	.00158	.00026	—	1.00627
No. 6, C. F., S. C. H.	.91700	.02750	.01350	.00700	.00200	trace	.00577	trace	.02896	.00062	.00043	trace	—	1.00385
No. 239, C. F., 32 pdr.	.92900	.02550	.01850	.00440	.00450	.00046	.00382	trace	.03041	.00048	—	trace	—	1.01765
No. 364, B. F., 32 pdr.	.91980	.02450	.00850	.00650	.00100	.00013	.00480	—	.02970	.00140	.00155	.00010	—	.99845
No. 366, B. F., 32 pdr.	.92540	.02800	.00150	.00730	.00200	—	.00738	—	.02317	.00061	.00170	trace	—	.99763
No. 21, F. P. F., 32 pdr.	.93030	.02650	—	.01020	.00050	.00065	.00888	—	.01303	.00024	.00158	.00070	—	.99401
No. 42, F. P. F., 32 pdr.	.93450	.02900	.00900	.00900	.00200	.00052	.01290	—	.01810	trace	.00158	.00026	—	1.01686
No. 46, F. P. F., 32 pdr.	.92890	.02700	.00700	.00980	.00100	.00039	.00040	—	.02172	trace	.00212	trace	trace	.99893
No. 225, F. P. F., 32 pdr.	.91420	.03250	.00450	.00820	.01150	—	.00711	trace	.01810	trace	.00264	trace	—	.99875

N. B.—The sample No. 18 was not in sufficient quantity for a complete analysis.

* No. 10 endured the extreme proof. No. 325, burst at 112th Service round. No. 301, burst at 208th Service round. Nos. 325 and 301, Hot-Blast Iron.

In order to show the propriety of the course of analysis we have pursued, we offer an outline of the process of reducing the ores of iron; by which, it will be learned how much the metal may be essentially modified by the presence of foreign ingredients.

The *ores of iron* contain that metal in the state of oxide, and are accompanied more or less by earthy matter. The oxides are—the *Magnetic* or *protoperoxide*, containing, when pure, the highest amount of metal; the *Peroxide*, which, when crystalline is called *Specular*, and *Red hematite*, when earthy; the *Hydrated peroxide* or *Brown hematite*, also known as *Bog ore* or *Pipe ore*, according to its mode of occurrence; the *Carbonate of the protoxide*, the crystalline variety of which is the *Sparry ore*, and the earthy variety, the *Clay iron stone* or *Coal-ore*.

The best practicable division depends upon the associated foreign matters, according to which iron ores are—1st. *silicious*, with silica as their almost exclusive earthy constituent, and embracing the greater part of the *Magnetic* and *Specular* oxides, and a small portion of the others; 2d. the *calcareous*, which are usually very silicious, and mostly confined to *Red hematite*; 3d. *magnesian* with talcose gangue of magnesia and silica, and the iron as magnetic oxide; 4th. *argillaceous*, containing alumina and silica, and including the earthy *Brown hematites*, and a large portion of *Clay iron stone*; 5th. *manganesian*, comprising the *Sparry ore* and some of the *Brown hematites*.

In *reducing iron ores*, the oxide is reduced to metal and its associates are fused into a slag or cinder, by the use of limestone as a flux. All the ores contain silica, but where it is alone or associated only with lime or magnesia, as in the first three classes, the fluxion of the earthy matter and consequent reduction of an ore is attended with difficulty. Hence, such ores are termed *hard*. On the other hand, when the silica is associated with alumina or oxide of manganese, as in the last two classes, the slag is much more fusible and reduction facilitated, and such ores are called *soft*.

The ores of the second class are often so very calcareous that the addition of limestone, as a flux, becomes unnecessary and even injurious. In such cases, where an argillaceous or manganesian ore is not to be obtained, the addition of clay itself renders them more easy of reduction; and the clay may be then regarded as the flux. As a general rule, a single ore rarely contains the ingredients in the due proportion required to flux it readily, and

hence the utility of mingling different kinds of ore. Either of the first three may be advantageously mixed with either of the two last classes.

The process of reduction is as follows: The ore, flux, and fuel, being thrown together into the top of the furnace, gradually descend, and the first operation to which the ore is subjected is reduction. Carbonic oxide gas, arising from the combustion of the fuel in the lower part of the furnace, reduces the oxide of iron to the metallic state. The next operation is the union of the flux and earthy matters into a fusible and flowing slag, by which the reduced metal becomes exposed to the cementing action of Carbon, and forms with it fusible Carburet of iron or Cast Iron. The fused metal and slag flow drop-wise to the bottom of the furnace, where they collect into two strata, the heavier metal below being covered by the lighter slag above it. The slag is drawn off from time to time, until the accumulated metal rises to the top of the damstone, when it is run into "pigs."

Constituents of Cast Iron.

The associated substances, always occurring with the ores in the furnace, are silica, lime, and alumina, in addition to which, sulphur, phosphoric acid, oxide of manganese, magnesia, and the alkalies, are rarely absent. Substances of more unusual occurrence are oxides of chromium, tin, titanium, vanadium, copper, arsenic, and some others. Now although most of these substances are reduced to their metallic state with great difficulty, by the fuel and high heat of the furnace, yet their affinity for oxygen is weakened, and the contact of a large quantity of metallic iron adds its influence to reduce portions of them to metal, in which state they enter into combination or admixture with the iron. Hence crude cast iron or pig iron, besides its essential constituent carbon, contains more or less of the elements of the ingredients above named, though always in small proportion to the iron, and in their total amount, rarely exceeding eight or ten per cent.

The influence of these associates upon the character of cast iron has been determined, to a limited extent, in the case of only a few of them: thus, a considerable proportion of manganese is said to impart a large, lamellar, and brilliant fracture and some degree of brittleness; phosphorus is supposed to render iron "*cold short*;" and sulphur "*hot short*." But the full extent of influence of these few is yet undecided, while the influence of most others is either unknown, or at least subject to great doubt.

Although most of the above are only occasional constituents, and exist, when present, only in minute quantities, still it was expedient that the examination should be made with a view to the detection of each and every one of them.

Pulverization.

It was found, after repeated trials, that the only sure way of obtaining samples of uniform composition, is to clip off pieces of the size of $\frac{1}{8}$ to $\frac{1}{16}$ of an inch diameter by means of a cold chisel and hammer. These were taken from the small broken cylinders, which had been bored from the muzzle of the gun and served for the mechanical tests. Reduction under the pestle and sifting should be avoided, for any process which requires that the metal shall be acted upon in a *state of powder*, is defective; because the slag and graphitic carbon being, as it were, mere mechanical components pervading the mass of iron, and not chemically combined with it, form finer particles by pulverization, which, from their small specific gravity, fly off partly as dust. This loss, and the difficulty of reducing the metallic granules to the same state of fineness as the siliciuretted and carburetted constituents of the metal, prevent the possibility of obtaining a mixture sufficiently uniform to afford a fair average sample. We found that equal portions of the same powder gave under the same circumstances variable results, whatever solvent was employed. Thus, one gramme digested in nitro-muriatic acid gave, of insoluble residue, in two sets of experiments similarly conducted:—

Total Insoluble Residue.

		1st.	2nd.
No.	10 F. P. F.	.0456	.0486
"	225 "	.0480	.0682
"	46 "	.0436	.0568
"	47 "	.0460	.0612

These were selected indiscriminately from more than fifty experiments, all of which yielded results that are equally conclusive. In several trials, the proportion of insoluble residue obtained from the samples of *dusty* metal, presented a greater variation than those from the clippings, or even the fine granules. The discrepancy arises from the facts just mentioned. It is also because the mixed metal in its finest state of comminution, is peculiarly

sensitive to a decomposing or transforming action of the digesting liquids; which, instead of being confined solely to effecting solution of the metallic bases, extends to the transmutation of some of the other constituents into soluble matter, as will be treated of in the paragraphs relating to the estimation of carbons, slag, and silicium. It is therefore imperative, that:—

1st. In reducing the metal, mechanically, it must be to clippings and not to powder. The size should be from $\frac{1}{8}$ to $\frac{1}{10}$ of an inch diameter, as this bulk is better adapted to insure a gradual reaction and uniformly exact results.

Total Amount of Carbon.

The important bearing of this ingredient upon the quality of cast iron, renders its accurate estimation of paramount importance; for the metal is classified into *gray* and *white* varieties, according to the conditions in which the carbon exists in it. For instance, in gray iron there is both combined and free (graphitic) carbon; while in the white, the carbon is wholly or nearly all combined with the metal. Now, as the only way of accurately determining the former condition is by detecting the graphitic from the totality of carbon, it is essentially important that these last two shall be estimated with great precision. The most usual method of determining the whole of the carbon is, to ignite five grammes of the finely powdered metal, in a combustion tube, with a mixture of anhydrous chromate of lead and chlorate of potassa, or with oxide of copper. By the aid of high heat and the oxygen generated by the decomposition of those highly oxidizing bodies, the carbon burns off as carbonic acid, and is condensed by caustic potassa contained in a bulbed receiver. The increase of weight, which the latter acquires by the process of combustion, represents the amount of carbonic acid absorbed; whence the total amount of carbon is calculated.

This plan, although expeditious, is liable to many objections, the chief of which is the necessity of having the metal in an impalpable powder, in order to effect its complete combustion. This entails the disadvantages enumerated in the paragraph upon *pulverization*. It will also be necessary, in most cases, to repeat the ignition in order to check doubtful results.

Another, and very accurate, method is that proposed by Berzelius, and which consists in depositing a weighed lump of five grammes of metal upon a fused cake of 30 to 40 grammes of chloride of silver, in a vessel containing

water, and closely covered to prevent access of air. A little hydrochloric acid is added to promote the action. The silver salt, gradually decomposing, gives up its chlorine to the *bases* of the metallic iron, which, by the union becomes soluble in the water as chlorides, while the eliminated carbon, silicium, and slag, subside to the bottom upon the silver cake, which is more or less reduced to the metallic state. The liquor being filtered off through a small paper, the undecomposed portion of chloride of silver is removed with a platinum-pointed pincette, freed of adhering particles by means of the washbottle, and reserved for use at another time. The contents of the filter, while still moist, are to be rinsed out into a beaker, treated with dilute nitric acid and gently warmed, to dissolve the reduced silver powder and any traces of oxide of iron. Great care must be observed to provide against too much heat, so as to prevent portions of the carbon from being converted into soluble matters. When the whole of the silver and oxide of iron has been taken up, the liquor is filtered on a balanced filter, which is washed with hot water, dried first in a hot air-chamber, and finally in vacuo, and weighed. The gross amount of carbons, silica, and slag, is thus obtained. By ignition, the whole of the carbons is burned off, and the amount is determined by weighing the calx. The difference between the two weights, which is the amount lost by the ignition, represents the carbon.

Solution of chloride of copper has been suggested as a substitute for the solid chloride of silver, and its action is more energetic and rapid, but the objection to the plan is that a small portion of the carbon is lost as carbon-hydrogen gas.

The above plan has the advantage of giving the total carbon in one operation, but it is tedious, time-consuming, and only manageable with difficulty. Ten or twenty days are necessary for the perfect completion of the operation, and if any air should accidentally enter the digesting vessel, the consequent formation of hydrated peroxide of iron is a serious impediment to the progress of the reaction. The traces of hydrochloric acid, with which the water may be acidulated, tend to prevent the generation of this oxide, but it must be used sparingly, since, otherwise, by taking up some of the metallic iron, a part of the carbon might be driven off. Free chlorine has also been proposed by Berzelius, but its use is less practicable than the preceding method, because bulbed glass apparatus, requiring nice arrangement and careful management, must be employed by his mode. There is,

moreover, difficulty in volatilizing all the chloride of iron formed, and also in preventing the access of air, which, by its oxygen, will convert some of the carbon into carbonic acid, or oxide, or both.

Another process, by the same distinguished chemist, consists in subjecting the iron, in filings, to the spontaneous action of dilute, but perfectly pure, nitric acid, added portionwise. It is time-consuming, and requires great attention to insure uniform reaction, for much heat is eliminated and may raise the temperature of the mixture above 125° F., and thus promote the transformation of a portion of the carbon into soluble matter, as mentioned in the paragraph relating to graphitic carbon. Moreover, a basic salt of iron, soluble with difficulty in cold acid, is likely to be formed. Besides, if any of the foreign alloys are convertible into insoluble oxides by the nitric acid, they remain with the carbon and silicium; and in the after-separation of the former from the latter by ignition, they may, by entire or partial volatilization with the carbon, lead to error in its estimation.

Berthier's process of estimating the total amount of carbon, by slowly oxidizing the iron by exposing it to air and moisture, is tedious and tends to error, from the facts, that the hydrochloric acid, required in the after part of the operation to dissolve out oxide of iron, as well as the subsequent evaporation to dryness, to render the silica &c. insoluble, subject the carbon to a partial conversion into soluble humus.

After repeated trials and due consideration of the above and other processes for estimating the total amount of carbon, we were convinced that none of them possessed that union of speed and accuracy which is necessary to a satisfactory performance of the analysis. We, therefore, abandoned them, and proceeded to a course of experiment, with the view of elaborating a process which would be rapid as well as reliable; and succeeded in developing the following method:—

2*d*. One gramme of metal clippings, having been accurately weighed, is placed in a small beaker with the atomic proportion of iodine, say five grammes of iodine to one of metal. A little water is added, and the glass, with its cover on, left at rest in the cold. Five to six hours suffice for completing the solution of the bases, and the rapidity of action is inversely as the state of dilution of the liquid; so that only enough of water to cover the mixture should be employed. Perfect solution is recognized, in the dark brown liquor, by the flocculent character of the insoluble matter as compared

with the heavier and metallic particles, and if any of the latter still remain unacted upon, they will subside heavily to the bottom. In such case, a few more grains of iodine must be added, if the first portion has entirely dissolved, and the digestion arrested by filtration, as soon as the solution of the metal has been accomplished; for a prolonged action of the iodine, as well as too great dilution, promote the oxidation and volatilization of the carbons.

Great care must be observed to temper the reaction, which, when violent, gives off a distinct odor analogous to that of chloride of sulphur. Slight additions of water, therefore, become occasionally necessary, for undue warmth is apt to induce the conversion of a portion of the carbon into soluble matter. This reaction is particularly evident when the metal is in very fine powder. Water is probably decomposed, the oxygen going to the carbon and iron, and the hydrogen to the iodine, which then, in its compounded hydriodic acid form, unites with the oxide of iron.

For example, we present a few results selected indiscriminately from over an hundred equally conclusive, which not only show the difference between the digestions with iodine at hot and cold temperatures, but also the inequality of the "hot carbon" results, owing to the difficulty of so regulating the heat as to produce uniformity of reaction.

Clippings digested with Iodine in the Cold.

Powdered Metal digested with Iodine on the Sand Bath.

		Total Carbon.		Total Carbon.	
		1st.		1st.	2nd.
No.	17, W. P. F.	.046		.037	
"	28, C. F.	.039		.024	
"	45, F. P. F.	.038		.028	
"	7, "	.045		.022	
"	301, W. P. F.	.042		.0085	.024
"	239, C. F.	.044		.034	
"	21, F. P. F.	.026		.016	
"	12, "	.033		.029	.0285
"	54, C. F.	.039		.0255	.0380
"	46, "	.034		.016	.0255

When it is evident that no fine particles of metal remain at the bottom of the beaker, the solution is perfect; and the insoluble matters, consisting

of all of the carbon, slag, some silica, and a portion of oxide of iron formed as mentioned under "Slag and Silicium," float in the liquid, which contains the bases or remaining constituents, as iodides. The solution is to be immediately diluted with water, filtered through a balanced filter, washed with hot water; then with hydrochloric acid, to remove traces of sesquioxide of iron; and finally, with hot water. The filter is then first dried between the folds of bibulous paper, and subsequently in vacuo along with the counterpoised paper. The two are then weighed against each other, and the difference of weight denotes the amount of insoluble residue. As this latter does not consist wholly of carbon, but also contains slag and some silex and perhaps alumina, the filter must be transferred to a platinum crucible, cautiously ignited over a lamp, and finally by the blast, until every particle of carbon is burned off, as may be known when the residual calx presents no black specks, and again weighed. The loss by ignition represents the *Total Amount of Carbon* contained in the iron, and is to be determined by deducting the weight of the calx from the weight of carbons and calx combined.

The filtrate is rejected, because of the large excess of iodine which it contains; as the evaporation to dryness with hydrochloric acid, requisite for its expulsion, would so diminish the phosphoric acid as to render its estimation from such a solution inaccurate.

Graphitic or Allotropic Carbon.

We have already stated that the carbon in cast iron may exist in two conditions, combined and free. In the latter or free state, it is usually termed graphitic carbon, from its identity with native graphite or plumbago; possessing the same chemical composition—*i. e.* being essentially pure carbon—and the same external characters of scaly structure, color, greasy feel, and softness. Regarding the diamond as one form of pure carbon, and graphite as another, they have been termed *allotropic* conditions of that element, and in speaking of the uncombined variety we have termed it *graphitic*.

White cast iron contains all the carbon in a state of combination, if it be rapidly cooled after fusion; but by slower cooling, a portion of the carbon is eliminated or precipitated through the mass in the form of graphite, the black scales of which contrasting with the whiter color of the metal give the appearance of *gray* iron. When the precipitation takes place only

in parts, the metal is termed *mottled*. This artificial graphite is equally resistant of chemical agents as the native plumbago; and since the combined carbon, when separated from cast iron by chemical agency, is easily acted upon, we availed ourselves of their different behavior to determine their relative quantities.

In our first essays, we followed the method of Karstan for estimating the graphitic carbon, because it had the sanction of high authority, but we found by experience that it is unsatisfactory. The process consists in dissolving a given weight of the powdered metal in nitric acid, by gentle heat, adding a little hydrochloric acid towards the end of the digestion to insure the solution of any undecomposed silicide, oxide, or phosphide not wholly soluble in single acids, and to prevent the formation of insoluble subnitrates, which are apt to be generated when nitric acid alone is used. After perfect solution, the whole is passed through a balanced filter, washed with hot caustic potassa solution, to remove extractive matter; then with hot water and hydrochloric acid, and again with hot water. The filter, after being dried between paper, and in vacuo with its counterpoise, is weighed against the latter. The difference between the two expresses, quantitatively, the contents of the filter, which consists of carbon, slag, and some little, perhaps, of silica. They are separated by transferring the filter to a platinum crucible, igniting, and reweighing. The calx remains, but the carbon is burned off, and the loss in weight indicates its amount.

It is so very difficult to regulate the action of the nitric acid, that inequality of results is unavoidable. For example, carbon is variably sensitive to the action of nitric acid, according to its strength, and the temperature. At the moment of elimination, it is in an impalpable state, which is peculiarly conducive to chemical action. Nor is this behavior confined solely to the combined carbon, for under the unavoidable circumstances of the digestion, the graphitic carbon is likewise altered, as is proved by the few following examples, selected from a series. Graphitic carbon is particularly changed by the prolonged digestion which is necessary to effect perfect solution; and if *fuming* nitric acid is added to facilitate the reaction, the complexity of the change is augmented, and an irremediable source of error created. The annexed results not only lack uniformity in the two series, but also show in the first a much less proportion of graphitic carbon than

really exists in the iron, as is confirmed by the results of a correct process given on the succeeding page.

Graphitic Carbon.

	1st. Essay.	2d. Essay.
*No. 10, F. P. F.	.0106	.0294
" 225, "	.0150	.0350
" 46, "	.0156	.0350
" 47, "	.0160	.0314
" 301, W. P. F.	.0210	.0085

Even slight differences in temperature and strength of acid induce important changes, and after some thirty experiments with results like the preceding, we abandoned Karsten's process as erroneous in principle and fact, and, consequently, discarded the results obtained by it. The essays to which the disappointment led were more propitious, and ended in a modification of Bromeis' process, which fulfils every requirement.

Graphitic or Allotropic Carbon.

3d. The Graphitic Carbon is to be estimated by digesting one gramme of clippings of metal, at a gentle heat, with hydrochloric acid of specific gravity 1.1. In a few hours, the soluble ingredients of the metal will have dissolved, leaving the Carbon in flakes or lumps, along with some Silica, floating or suspended in the liquor. The sediment is to be collected upon a counterpoised filter, washed with hot solution of potassa of specific gravity 1.29 to remove humus and extractive, then with dilute hydrochloric acid, and finally with hot water. The last washing must be thorough, because if any alkaline chloride is retained, being volatile, it will mostly pass off with the carbon during ignition, and thus cause error in the determination of the latter. The filter is then dried, first between folds of paper, and subsequently in vacuo with its counterpoise, and the two are afterwards

* N. B. These results, as well as those given under the head of *Total Insoluble Residue* and *Total Carbon*, were taken from the record of nearly a thousand experiments instituted for the purpose of devising speedy and exact methods of determining severally the Combined and Graphitic Carbon, the Slag and Silicium. We have cited only a few cases, because it would require too much space to report the whole number.

weighed against each other, and the difference in weight noted. It will be observed, on examination, that the Carbon is in scales and remarkably free from dusty particles. The filter and contents are now to be transferred to a platinum crucible, ignited cautiously over a Russia lamp, and weighed. The loss by ignition expresses the *amount of Graphitic Carbon* contained in the sample, and may be ascertained by weighing the calx and deducting its weight from the original weight of the filter and contents. There are certain requisite precautions to secure the accuracy of this process. Great care must be observed in the ignition to burn off all the Graphite, so that not even a black speck may be visible in the calx. All drafts must likewise be prevented, lest particles of the calx may be accidentally blown off and error thus occasioned, since the loss by wind would be estimated as loss by ignition, and the amount of Graphite thus erroneously augmented.

In the reaction with the acid, it is designed to restrict the agency of the hydrochloric acid, as to the carbons, solely to the conversion of that which is in a combined condition into gaseous carbohydrogens and humus, which is easily soluble in a solution of caustic potassa. We have, however, found that it is necessary to limit its strength in order to effect this change without simultaneously altering the Graphitic Carbon. For example, if the density of the acid is too great, and the temperature too high, the results will be variable and unsatisfactory, as is proved by the following experiments.

Graphitic Carbon.

		1st.	2nd.
		Strong Acid.	Weaker Acid.
No.	17 W. P. F.	.0159	.0170
"	119 "	.0110	.0042
"	27 C. F.	.0152	.0095
"	344 B. F.	.0181	.0138
"	18 W. P. F.	.0055	.0130

It is evident, therefore, that strong acid and a high temperature not only cause the entire transformation of the Combined, but induces a partial alteration of the Graphitic Carbon, so that the results will be constantly varying according to the varying circumstances, and to the prolongation of the digestion. On the other hand, the acid must not be too dilute, nor the temperature too low, else the converse of the above will happen; and, owing

to deficient action, a portion of the Combined Carbon, instead of having passed off in gaseous and soluble forms, will remain in fine powder with the Graphitic Carbon, to contaminate it, and hinder its correct estimation. A little experience and care will insure a well conducted manipulation, and consequently correct results.

Combined Carbon.

4th. The Combined Carbon, is estimated after the estimation of the "Total Carbon" and the "Graphitic Carbon," separately, by deducting the weight of the latter from that of the former. The difference expresses the *amount of the Combined Carbon*. As this method, by subtraction, is the only available one, it is therefore imperative to have correct figures, in order to obtain accurate results.

Silicium and Slag.

Having believed that the Silicium and Slag, either conjointly or separately, are important constituents as influencing the quality of cast iron, our experiments for separating and estimating them accurately, were numerous and varied. The Silicium is a chemical component of the iron, while the Slag is a mechanical ingredient, pervading its mass like the Graphitic Carbon. This Slag also contains silicium, but as silica, and in combination with earthy bases and oxide of iron; hence, in separating the Silicium of the metal, it is necessary to avoid decomposing the Slag at the same time, and thus taking up also a portion of its silica or bases.

The Silicium exists originally in combination with the metal as silicide of iron, and becomes oxidized into silica during digestion with acids, &c. The Slag is an accidental ingredient. It is, therefore, important to determine quantitatively these two conditions; a task not without difficulty, owing to certain similarity in the behavior of Silex and of Slag, respectively, to the reagents necessary to be employed as solvents. It is necessary to digest a new portion of clippings for the estimation of these components. The filtrate from the digestion with Iodine, for "Total Carbon," as well as from that with hydrochloric acid, for "Graphitic Carbon," will not answer, for the following reasons:—

In the Iodine digestion, at cold temperatures, all the Iron is taken up; but a portion of the Alumina, as Phosphate, and probably Lime and Mag-

nesia, are left with the untouched Carbons, Silica, and Slag, so that these would not be correctly represented by the weight of the insoluble residue. In numerous essays, repeated for verification, the quantity of the so-called Slag and Silix, was invariably larger than that obtained with nitric or hydrochloric acid. Moreover, as it is difficult to prevent access of air, a small quantity of a basic salt is formed, which is not entirely removed by the hydrochloric acid used in the final digestion, but tends to unite with the Silica during ignition, and form a Silicate resembling Slag, whereby the normal Slag is contaminated.

The Aluminium, Calcium, Magnesium, and Phosphorus, are oxidized by the Oxygen of the water, in the presence of the Iodine. The large amount of Slag always obtained by the digestions with Iodine induced, at first, the belief that the Oxide of Iron associated with it was free, and had originally existed as such in the metal, and being an oxy-base was not touched by the Iodine, nor yet by the Hydrochloric Acid formed, owing to a deficient quantity of the latter. This view was founded on the fact that digestion in acids, especially the hydrochloric, which leaves no basic salt, always gave less Slag. Nor can the Slag and Silicium be estimated from the Hydrochloric digestion for Graphitic Carbon, because the solution would, in that case, have to be evaporated to dryness before filtration in order to render all the Silica insoluble—a process which, by concentrating the acid and augmenting the temperature, might endanger the partial conversion of the Carbon into soluble humus and extractive. Besides, the strength of the acid, for the gaseous transformation of the Carbon, would have to be necessarily so high, that it might decompose the Slag. The only course is to take a new position, and to treat it as follows:—

5th. One gramme of clippings of metal, having been accurately weighed, is to be placed in a wide-mouth flask. A funnel and a drying tube, filled with fused chloride of calcium, are adapted to the flask by means of a tightly fitting cork, and an exit tube, drawn out to a fine opening at its extremity, is fitted, in like manner, to the further end of the drying tube. Having made certain, by actual examination, of the tightness of the joints, chemically pure hydrochloric acid, of specific gravity 1.06, is then poured into the flask through the funnel tube, and the flask slightly warmed to start the action. Gases are soon generated, and after having passed over, a sufficiently long time to expel all atmospheric air from the interior of the

flask, a lighted taper is applied to the fine orifice of the exit tube, so as to ignite the issuing jet of arseniuretted or mixed gas, which is formed from the elements of the contents of the flask. The burning jet is projected against a piece of cold white porcelain. If, after five minutes of uninterrupted combustion, there is no adhesive Tache formed upon the porcelain, it is evident that there is no arsenic, since this process detects less than $\frac{1}{50000}$ part of a grain of that metal with certainty. Great care must be observed with regard to the character of the Tache, for Phosphuretted and Antimoniuretted Hydrogen Gas both give dark stains in a similar reaction. If it is not adhesive no attention need be given to it, as it is merely a distillate of oily carbohydrogens, or phosphorous sublimate. Moreover, if it is a long time in being generated it may be estimated as a trace, but if it is large and distinct, and prompt in appearing, then it must be quantitatively determined from the same sample as the Sulphur, as hereinafter directed. This precaution about the Tache is particularly necessary also for the reason, that the odor of the Phosphuretted Hydrogen, as eliminated when iron is dissolved in hydrochloric acid, so nearly resembles that of the corresponding Arsenic Gas as to be mistaken frequently for it. In the reaction the Water is decomposed, its Oxygen goes to the Iron, which then unites with the acid, while its Hydrogen, in the nascent state, joins with the eliminated arsenic, and antimony, and phosphorus, and passes over in a gaseous inflammable state. The qualitative test for Arsenic, at this stage of the process, is a convenient saving of the time and trouble of a separate digestion, and is no hindrance; for when the test is completed the apparatus is to be taken apart, and the flask, covered with a watch-glass, transferred to the ledge of the sand-bath and there left until the residue becomes flotant. Solution is then complete, and the liquid must be evaporated to dryness, redigested in very dilute hydrochloric acid, filtered, washed with hot water and hydrochloric acid, and lastly with hot water. After drying the filter, it is ignited in a platinum crucible over a "Russia" lamp, to burn off carbon, and then weighed to ascertain the amount of residual calx, which consists of Silica and Slag.

Care must be taken not to use acid stronger than specific gravity 1.06, or the Slag will be attacked, and its bases dissolved. Nor must it be weaker, as it will then cause loss of time in the digestion. The insoluble portion on the filter must be invariably washed with hydrochloric acid, to

remove any traces of Iron or Oxide that may remain accidentally, and which would afterwards add undue weight to the Slag, for it is not removable by subsequent boiling with Potassa solution.

Having obtained the Silica and Slag together, and accurately noted their united weight, they are transferred from the platinum crucible to a small silver capsule, and boiled for two minutes with a half fluid-ounce of Caustic Potassa solution of 1.10—(Spec. grav. 1.25, diluted with two volumes of water). After sufficient repose for the subsidence of all suspended particles—which, from their extreme fineness, would otherwise pass through the paper—it is filtered on the finest paper, and washed with hot water, until the filtrate leaves no stain when heated to dryness on a platinum spatula. Silica is dissolved, and the Slag remains untouched.

Ley of greater density than above described would decompose the Slag, by abstracting its Silica, while a lesser strength would not take up all the free Silica. Nor is Carbonate of Soda, even in dense solution, a good substitute, for, although it may imperfectly dissolve Silica while boiling, it cannot retain it on cooling, but drops it, partly in a free state, and partly as soluble Silicate of Soda. The strength before directed has been found, by experiment, to answer best; it takes up the Silica while hot, and retains it on cooling, but does not attack the Slag.

After the filter has been washed and dried, it is ignited in a platinum crucible and weighed. The weight expresses the amount of *Slag*, and this, deducted from that of the Silica and Slag united, gives the proportion of soluble Silica, whence its contents of *Silicium* is to be calculated.

Calcium, Magnesium, Sodium, Potassium, Cobalt, Nickel, Iron, Manganese, Aluminium, Copper, and Phosphorus.

Another portion of metal is required to be digested for the estimation of these components, because the filtrate from the Carbon, by digestion with Iodine, does not contain all the Phosphorus and Alumina, as has already been stated at page 408. The filtrates from the digestions in hydrochloric acid, for Graphitic Carbon, and for Silica and Slag, have also lost a portion of their Phosphorus, which, during the digestion, passed off as Phosphuretted Hydrogen Gas. Moreover, some of the above constituents are in such small proportions that they cannot be determined in one

gramme, the quantity used in the aforementioned digestions. The proper course, therefore, is to proceed as follows:—

6th. Five grammes of clippings of metal are placed in a beaker of eight ounces capacity, drenched with fuming nitric acid, covered, and set aside in a cool place; for, if heated immediately, the reaction would be so violent as to eject particles. After twelve hours, pure nitric acid is added, and the beaker transferred to the extreme end of the sand-bath, so that it may not be subjected to a higher heat than 212° Fahr., as Phosphoric Acid will volatilize, above that temperature, from solutions containing free acid.

When the solution is perfect, as may be known by the flocculent appearance of the insoluble particles, the cover is removed, and the liquor allowed to evaporate gradually to dryness. Hydrochloric acid is added, the cover replaced, and digestion continued until re-solution is effected. The addition of hydrochloric acid is necessary to insure the entire solution of all the oxide as well as, basic salt which are formed by the nitric acid, but are insoluble in it or in water alone. Besides, some Phosphide of Iron, which can only be entirely dissolved in hot Aqua Regia, may otherwise remain, because of its insolubility in nitric acid alone. Hydrochloric acid alone would not answer, for, as before stated, it would dissipate most of the Phosphorus as Phosphuretted Hydrogen Gas. By this prolonged treatment—which, if pursued as we have directed, causes no loss of Phosphoric Acid—the Iron, Chrome, Manganese, Aluminium, Calcium, Magnesium, Sodium, Potassium, Cobalt, Nickel, and Copper, are entirely dissolved, and remain in the liquid; while the subsident matter contains part of the Carbon, all of the Silex and Slag, together with Tin and Titanium as oxides, if the latter are present in the metal. It is requisite that the hydrochloric acid used in the redigestion be strong, otherwise the Alumina, which loses its acid by evaporation, becomes difficultly soluble.

As dense metallic solutions, particularly when acid, are apt to clog the filter, the liquid is next to be diluted with water, so as to facilitate the filtration, then filtered through fine paper, and well washed with hot water. The filtrate is *A*, and the filter *a*. The latter is set aside for subsequent treatment for Tin and Titanium.

To the filtrate *A*, aqua ammoniæ, free from carbonate, is added in excess; Alumina, and the oxides of Chrome, Manganese, and Iron, with Phosphoric Acid, are precipitated, while Lime, Magnesia, Cobalt, Nickel,

Copper, Sodium, and Potassium, remain in solution. The presence of ammonia in excess holds up the Copper, Cobalt, and Nickel; and that of ammoniacal salts, as a general rule, also retains the Manganese in solution, as well as the Magnesia, but where the Iron with which the Manganese is associated is so largely in excess as in the present instance, the latter is wholly precipitated with the former. Of numerous essays, there are very few in which even traces were left. If the solution is not acid, previous to the addition of aqua ammoniæ, some muriate of ammonia must be added. Immediate filtration should always follow the treatment with aqua ammoniæ, to avoid the transfer of Carbonic Acid from the air to the Lime, and the consequent precipitation of Carbonate of Lime. The filter is well washed with hot water and set aside, as *b*, for the present.

6th. Calcium, Copper, Cobalt, Nickel, and Magnesium.

The filtrate *B* will have a bluish tinge, if any Copper is present, and is to be evaporated to a dense solution, mixed with twice its volume of absolute alcohol, and the Lime precipitated by a few drops of sulphuric acid. The Sulphate of Lime is filtered off, washed with dilute alcohol, ignited, weighed, and the amount of *Calcium* calculated from the Sulphate.

The filtrate from the Lime is then evaporated very cautiously to dryness, and heated to expel every trace of ammoniacal salt. In case the sulphuric acid should be in excess, it is well to neutralize it with a piece of carbonate of ammonia, to be added after the evaporation and previous to the heating—which must be to slight redness, and continued until the weight of the crucible and contents remains constant. This expresses the weight of the Sulphates of Potassa, Soda, and Magnesia, with traces of Copper, Cobalt, and Nickel, if they should be present.

The saline mass is dissolved in water, and the solution divided into two equally weighed portions. In the analysis of some Silicates, a small insoluble residue is apt to be left in making this solution, and it consists chiefly of Manganese and Silica; but in the present analysis such residue is not observed. One portion of the solution is heated with chloride of barium, to precipitate Sulphate of Baryta, from the weight of which, the Sulphuric Acid, doubled, expresses the whole amount of this acid in the joint weight of the Sulphates above determined. The excess of Baryta being removed from the solution by Sulphuric Acid, Sulphuretted Hydrogen is passed

through the solution, whereby Sulphide of Copper, if present, is precipitated. The Sulphide of Copper and Sulphate of Baryta are filtered off, and the *Copper* determined, if necessary, by re-solution of the Sulphides in Nitro-muriatic Acid, after removal from the paper, and by precipitation when boiling with Potassa. The solution filtered from the Sulphide of Copper is tested for Cobalt and Nickel, by adding ammonia, and a few drops of sulphide of ammonium, and then acidulating carefully with hydrochloric acid. A black Sulphide remaining indicates *Cobalt* or *Nickel*, and may be further tested, but we have hitherto found only traces of these metals in the present analyses.

The second portion of the solution of joint Sulphates is treated with ammonia and phosphate of soda, whereby the ammonia-phosphate of Magnesia is thrown down. It is filtered, washed with ammoniacal water, dried, burned off, and the amount of *Magnesium* calculated from the weight of the Phosphate of Magnesia, which is to be doubled.

6th. *Potassium and Sodium.*

Having determined the Magnesia, and the total amount of Sulphuric Acid in the joint Sulphates, the relative amounts of Potassa and Soda may be calculated by indirect analysis, or by a simple equation. By calculating the amount of Sulphuric Acid required by the Magnesia, which happens to be just twice its weight, and subtracting this from the total amount of Sulphuric Acid in the joint Sulphates, we have the amount of Sulphuric Acid, S , combined with the alkalies. Further, by subtracting the weight of the Sulphate of Magnesia from that of the joint Sulphates, we have the weight of the alkaline Sulphates, from which, if their Sulphuric Acid be taken, the remainder is the joint weight, a , of the alkalies. Then $2.9136a - 2.258 S =$ the weight of Potassa. This, subtracted from a , gives the weight of Soda. The metals, *Potassium* and *Sodium*, are calculated from the weights of their Oxides.

This method of indirect analysis we have found practicable, when the quantities to be weighed are such as to throw the errors of observation into the hundredth place, and where there is not too great a preponderance of one alkali.

In our first essays, we separated the Lime from filtrate B with oxalate of ammonia, filtered it off, evaporated the filtrate in a porcelain capsule under

paper cover (to avoid dust), ignited to expel ammoniacal salts and chlorine from Magnesia, and, towards the end, added a little oxide of mercury to insure the expulsion of the last trace of chlorine that might remain, and again heated to redness to drive off excess of mercury. The Magnesia was thus oxidized and rendered insoluble, while the residual components remained soluble. The capsule and contents having been weighed, and the weight of capsule deducted, the remainder was noted as the gross weight of Magnesia, Alkalies, Cobalt, and Nickel. The latter three being as Chlorides, the proportion of radicals was calculated accordingly.

The presence of Cobalt, and probably Nickel, was recognized in this method by the pink tinge in the evaporated saline mass, but their quantity was too small for estimation. The soluble matters were dissolved out by hot water, and the insoluble Magnesia separated by filtration, dried, ignited, and weighed. Its weight, deducted from the gross weight of the Magnesia and alkaline Chlorides, gave the amount of the latter, whence was calculated their proportion of radicals.

It is very difficult, even with the most skilful manipulation, to prevent a partial volatilization of the alkaline chlorides at the temperature necessarily used in the ignition, especially in a current of air, and where a quantity of ammonia salt is sublimed, but yet it has hitherto proved the more accurate method. Since, however, the quantities of alkali in these analyses proved exceedingly small, we preferred the former process, and determined only the joint amount of Potassa and Soda.

The contents of filter *b*, consisting of Oxides of Manganese, Chrome, and Iron, with Alumina combined with Phosphoric Acid, are carefully transferred from it, with a porcelain spatula, to an eight-ounce beaker glass. The filter is washed with hot water, dilute hydrochloric acid, and lastly with hot water, to remove every trace of Iron solution that may be retained in the pores of the paper.

This process of solution, by displacement of the portions of Iron adhering to the filter, saves time, trouble, and loss, as it reduces the number of filtrations which would otherwise be necessary if the filter with its contents had been jointly digested.

6th. Manganese.

The filter containing nothing is rejected. The filtrate, holding in solution the entire contents of the filter, is to be neutralized with aqua ammoniæ, and then treated with a slight excess of hydro-sulphide of ammonium, and immediately afterwards with two fluid drachms of Caustic Potassa solution of Specific gravity 1.30. All the Iron, as well as Manganese, precipitates as Sulphide, but the Alumina and Chrome are retained in solution by the Potassa. As soon as the precipitate has wholly subsided, but not until then—and it is, therefore, well to promote the separation by gently warming the liquor upon the ledge of the sand-bath—the pure supernatant liquor is filtered off, and six fluid drachms of Caustic Potassa solution, of specific gravity 1.30, added to the sediment, and the whole digested for a few minutes on the sand-bath, to insure the removal of every trace of Alumina and Phosphate. It is then diluted with water, filtered on the same filter as employed for the first liquid, and washed with dilute hydro-sulphide of ammonium to prevent the formation of soluble Sulphate of Iron by the action of air and water. The filtrate is *C*, and the filter *c*.

The filter *c* contains Iron and Manganese as sulphides, and its contents must be digested in nitric acid, filtered, and washed, to separate any unoxidized sulphur. Hydrochloric acid cannot be substituted for the nitric, as it is absolutely necessary that all the Iron shall be in a state of peroxidation, because if any of it is protoxide it remains in solution with the Manganese and leads to error. If the Potassa was not entirely removed from it by hot washing, previous to the digestion, it will now exist in the liquor as sulphate and nitrate, and, being an impediment to the after-steps of the process, must be removed. This is done by precipitating the Iron and Manganese by ammonia, washing with hot water, and redissolving in hydrochloric acid. When the solution has become cold, it is ready to be treated for the separation of the Manganese from the Iron, which is accomplished by adding a slight excess of pure carbonate of baryta, portionwise, setting aside for twelve hours, at the ordinary temperature, and stirring occasionally. When the reaction is completed, all the Iron has precipitated, while the Manganese remains in solution. The whole is to be filtered and washed with hot water. The filtrate is *D*, and the filter *d*.

The filtrate *D* is frequently cloudy, owing to the intimate suspension of

particles of carbonate of baryta and iron precipitate, which pass through the filter, and these must be separated to prevent their contaminating the Manganese by after solution in acid. The solution is, therefore, evaporated to one-fourth its volume, and the suspended matters, whose subsidence is thus effected, filtered off and added to the filter *d*. The evaporation answers the double purpose of concentrating the liquor sufficiently to insure the entire separation of the baryta salt, which is then removed by the addition of sulphuric acid, filtering, and washing with hot water. The filtrate is further evaporated under paper cover, tested with a drop of sulphuric acid, to be assured of the absence of baryta, and treated with a clear solution of carbonate of soda, in slight excess. The whole is well warmed on the sand bath, the precipitated *Manganese* filtered off, washed with hot water, ignited until the weight remains constant, and *the amount* of metal deduced by calculation. The Manganese is precipitated as Carbonate, but when highly ignited in contact with air, like all the other Oxides of Manganese, it becomes Mangano-Manganic Oxide (Mn_3O_4). To reach this state it requires prolonged heating, and consequently the ignitions and weighings must be repeated twice or thrice, as may be necessary, to ascertain when this condition is reached.

6th. Iron.

The contents of filter *d*, consisting of Peroxide of Iron with excess of carbonate of baryta, are transferred with a platinum spatula to a beaker glass,—the traces adhering to the filter displaced by hydrochloric acid and hot water, as directed at p. 415. After digestion with a little more hydrochloric acid until solution is complete, sufficient sulphuric acid is added to precipitate all the baryta salt as sulphate, which is then filtered off. Before filtration it is better to allow repose, so that the precipitate may subside, and leave a clear supernatant liquor. This passes the filter very readily, and when all of it has gone through, the pasty residue should be drenched with hot water, and poured upon the filter, and washed with hot water. The filtrate is less apt to be cloudy by this mode. A drop of sulphuric acid is to be added to the filtrate, to obtain assurance that there is no baryta retained in the solution. Beakers should be exclusively used as containing vessels in these separations of baryta, for glass shows much

more readily than porcelain, whether any suspended particles cloud the filtrates.

As the sulphate of baryta, precipitated from the Iron solution, tenaciously holds a portion of the latter, the former must be well washed on the filter, first with hydrochloric acid, and then with hot water. The consecutive addition of hydrochloric and sulphuric acids to the contents of filter *d*, is much better than the seemingly shorter plan of adding sulphuric acid direct and alone to the filter, and displacing the Iron as soluble sulphate, while the insoluble sulphate of baryta remains upon the paper. The latter mode endangers the carbonization of the filter and the introduction of soluble organic matter into the liquid which would, in a subsequent stage, prevent the entire precipitation of the Oxide of Iron.

The clear Iron solution, freed from baryta, is to be treated with aqua ammoniæ in slight excess, and the precipitated Oxide of Iron filtered off, and washed well with hot water. The filter is then thoroughly dried in the air-chamber, its contents detached, and the two ignited, separately, in a platinum crucible, to prevent reduction of Oxide by the Carbon of the filter. The metallic *Iron* is then calculated from the weight of Fe_2O_3 .

Certain precautions are necessary to success in separating Iron from Manganese by this process. At least twelve hours must be allowed for the precipitation of the Iron, after the addition of the carbonate of baryta; and to be satisfied that all has gone down, it is better to test a drop of the clear supernatant liquor with sulphide of ammonium. As sulphate of baryta is very liable to pass through the filter, care must be taken in every such event to promote its deposition by warmth and repose, and to separate it by refiltration.

Manganese is generally separated from Iron, when there are no other associates, by carefully neutralizing the hydrochloric solution of the two, with aqua ammoniæ, and then adding succinate of ammonia. The first is to retain the Manganese in solution, while the latter precipitates the Iron. But when the Iron is largely in excess, it is impossible to prevent the Manganese going down wholly, or nearly so, with it, even although the exact point of neutralization by ammonia, a very nice manipulation, is attained previous to adding the succinate. Besides, the wash water, especially if warm, may induce the formation of soluble acid succinate of iron, and carry away a portion of it through the filter. In the ignition of the succinate, there is also a difficulty in preventing the carbon of the succinic acid

reducing a little of the Oxide of Iron, when the quantity of the Succinate of Iron is large. This latter objection may, however, be partially obviated by washing the filter with cold ammonia instead of hot water. Herschel's method, with carbonate of ammonia—founded upon the fact that Fe_2O_3 of the neutral Persalts of Iron, is precipitated from the solutions of these salts by boiling, whilst Oxide of Manganese remains in solution,—and Scherer's, with caustic potassa, (which is a modification of it,) have also the disadvantage of requiring difficult manipulation, and very exact pre-neutralization, to insure the precipitation of the one, and the retention of the other. (Rose 2. 93.)

Henry's process (*Journ. de Chim. Méd.* 1850), without yielding any more accurate results than the carbonate of baryta plan, is tedious and time-consuming. Moreover, as organic matter is used, the Manganese may be partially retained in solution as Protoxide, and its correct estimation subsequently prevented. We give the preference to the carbonate of baryta plan, not because it is perfect, but on account of its superiority over all others at present known. In a more extended investigation, we should feel ourselves constrained to do what, but for want of time, we should have done in the present instance, and that is to devise a more reliable and speedy method, for even with the utmost care, the results obtained cannot be considered exact.

The filtrate C, contains the greater part of the Phosphoric acid in combination with the potassa, which was added with the hydrosulphide of ammonium. The remainder, which is a very minute portion, is with the Alumina, as a very basic compound, held in solution by the potassa.

In most of the processes heretofore followed by chemists in the analysis of Cast Iron, the obstinate affinity of Phosphoric Acid for Alumina has been overlooked, and that portion of it combined with the Alumina, owing to the difficult and time-consuming operation of separating it, disregarded in the determination of Phosphorus.

If any excess of hydrosulphide of ammonium was added, it remains in the filtrate, and the latter must, therefore, be digested with nitric acid for some hours, below 212° F. , to expel ammoniacal salt, and promote subsidence of unoxidized sulphur, which after twelve hours' repose must be filtered off. It is not advisable to take the shorter method, after adding the acid to separate sulphur, and pour in aqua ammoniæ to throw down

Alumina with the sulphur, hoping to expel the latter during ignition, for sulphur first precipitated redissolves under these circumstances. Care must also be observed to keep the heat always below 212° , or there will be loss of Phosphoric Acid by volatilization.

After the sulphur is separated by filtration, the filtrate is to be treated with a slight excess of aqua ammoniæ, the vessel covered with paper and heated upon the sand-bath. After a time cloudiness ensues, and Alumina falls down, and must be filtered off, washed with hot water, and set aside as *e*. The filtrate is *E*.

6th. *Phosphorus*.

The filtrate *E* contains only Alkaline Phosphates, and after being super-saturated with hydrochloric acid, is then to be treated with a nitric solution of .500 grammes of fine iron wire, carefully precipitated by aqua ammoniæ, filtered, the filter washed with hot water, dried and ignited, (paper separately,) and weighed. The excess of weight over the amount of Fe_2O_3 , that .500 grammes of iron should form by solution in nitric acid, is the amount of Phosphoric Acid which the quantity of *Phosphorus* in the filtrate makes; hence, the latter may be deduced by calculation.

To separate the remaining traces of Phosphoric Acid from the Aluminous precipitate, the latter must be dissolved in hydrochloric acid, and treated with tartaric acid until the solution ceases to give any precipitate by aqua ammoniæ. The tartaric acid prevents the precipitation of the Phosphate of Alumina by the ammonia. When barely supersaturated with aqua ammoniæ, a solution of sulphate of magnesia is added, containing so much of muriate of ammonia as will prevent the precipitation of the magnesia by the caustic ammonia. The magnesia carries down the Phosphoric Acid as triple Phosphate from the Alumina, the solubility of the latter being promoted by the tartaric acid. After several hours' repose, it is filtered, washed with ammonia water, dried, ignited, weighed, and the amount of *Phosphorus* calculated. It is added to that obtained from filtrate *E*.

6th. *Aluminium*.

The *Alumina* is next determined by evaporating the filtrate to dryness, burning off to charcoal, fusing the balance with bisulphate of potassa to

destroy the remaining carbon and render the Alumina soluble, redissolving in hydrochloric acid, precipitating by carbonate of ammonia, washing with water, igniting, and weighing.

When a large quantity of Phosphoric Acid and Alumina is to be separated, it is safer to redissolve the Alumina and treat it again in the same way with tartaric acid, magnesia, &c., but we have not found it necessary in the present Analyses. The Alumina obtained is to be tested for *Chrome*.

This method has been found to give the most reliable results. The separation of Phosphoric Acid from Iron alone, may be readily effected by several methods; but when Alumina is an associate of the Iron, then the task is very difficult and tedious, owing to the similarity of behavior of alumina, and its phosphate, to reagents, the affinity of Phosphoric Acid for alumina being very obstinate.

The process at first followed by us with great confidence was that of Berzelius, with some modifications by Rose and ourselves, and we only abandoned it after numerous and repeated essays had convinced us of its unreliability. The Iron, after the separation of the Manganese, and every other component except Phosphoric Acid and Alumina, was dissolved in Hydrochloric Acid, supersaturated with Carbonate of Soda, evaporated to dryness, transferred to a platinum crucible, mixed intimately with two parts of impalpable, fine, and pure Silica, and six parts of Carbonate of Soda to every one of Phosphate, and the whole highly heated to fusion for half an hour. The Silica is added to detach the Phosphoric Acid from the Alumina, while a part of the Carbonate of Soda combines with it at the moment of elimination, to form Phosphate of Soda. The remainder of the Carbonate of Soda unites with the excess of Silica. Here are two affinities simultaneously exercising their preference; and thus the Phosphoric Acid, as soon as eliminated by the Silica, which unites in turn with the Alumina it has displaced, is embraced by the Carbonate of Soda. Carbonate of Soda alone would not answer, for though it will, by *fluxing*, remove Phosphoric Acid from Iron, it does not separate it from Alumina.

After fusion, the fluxed mass was emptied from the platinum crucible into a silver capsule, and repeatedly boiled with water, filtered after each boiling, and the several liquors, or filtrates, united. The filter (1) contained all the Oxide of Iron and Alumina with free and combined Silica; the

filtrate (2) held in solution the Phosphorus as Phosphate of Soda, the excess of Carbonate of Soda, and some Silicate of Soda, formed during the fusion.

The content of the filter (1) was digested with Hydrochloric Acid for solution, then evaporated to dryness to render Silica insoluble, redigested in Hydrochloric Acid, diluted, filtered, and hot washed. The Iron and Alumina were in the filtrate, and the Silica remained upon the filter, and was discarded. It is inadvisable to throw the filter and its contents together into the beaker, for hot digestion with acid renders a portion of the organic matter of the paper soluble, and thus makes the subsequent precipitation of the Iron imperfect. It is much better to remove the Iron from the filter with a platinum spatula, and to displace the adhering traces with Hydrochloric Acid and hot water, as directed at p. 415. The filter may then be thrown away, as the washing with acid and water removes every trace of Iron and Alumina.

The filtered liquor was boiled in a silver capsule, with a slight excess of Caustic Potassa solution, filtered, and washed with hot water. To remove the Potassa obstinately retained by the Iron on the filter, the latter was redissolved in Hydrochloric Acid, precipitated by Aqua Ammoniae, filtered thoroughly, washed with hot water, and dried. The paper and contents were ignited separately, and weighed. The filtrate, which contained the Aluminate of Potassa, was supersaturated with Hydrochloric Acid, and then treated with Carbonate of Ammonia, which threw down Alumina as well as the Silicic Acid that remained in the liquid as soluble Silicate. After filtration, these two were separated by digestion in Hydrochloric Acid and evaporation to dryness, which left the Silica, and dissolved the Alumina. The latter was then precipitated from the filtered solution by Carbonate of Ammonia, dried, ignited, and weighed.

Now even at this stage of the process, there is a serious objection. In the first place, during the fusion with Carbonate of Soda, a portion of the Iron, as well as of the Alumina, will inevitably unite with some of the Silica to form a Slag, insoluble by subsequent digestion in acid; thus giving rise to an error in the estimation of both these ingredients. Moreover, the boiling with Carbonate of Soda may have caused the solution of traces of free Alumina as well as of Phosphate, either of which is partially soluble in a dense solution of Carbonate of Soda. These being passed into the Phosphate filtrate, serve to contaminate it.

The contents of the filter (1) having been estimated, the filtrate (2) containing Phosphate and Silicate of Soda, with excess of Carbonate of Soda, was neutralized with Hydrochloric Acid, to remove Carbonate of Soda, and then treated with a given weight of fine iron wire dissolved in Nitric Acid. The Phosphoric Acid was then precipitated with the Iron by Caustic Ammonia, redigested in Hydrochloric Acid, and evaporated to dryness, to remove any Silica that may have fallen with the Phosphate and Oxide of Iron, and the latter was then reprecipitated from the filtered solution with Aqua Ammonia.

The evaporation to dryness, as above directed, was very necessary, as some Silica invariably goes down; but the quantity is in proportion to the density of the solution—the more dilute the less is the quantity of Silica which precipitates. The evaporation of the Iron Solution with Hydrochloric Acid endangers the volatilization of the Phosphoric Acid, and prolongs the process; and we, therefore, endeavor to provide against these drawbacks, by igniting the mixed precipitates of Phosphate and Oxide of Iron and Silica, weighing, redigesting the calx in Hydrochloric Acid, filtering, washing with hot water, drying, and igniting the insoluble residue, and estimating the Oxide of Iron and Phosphoric Acid by loss. But there was almost invariably a fusion of a portion of the Iron and Silex into insoluble Slag, and a serious loss thus occasioned. Rose proposes (*Chem. Gaz.* 8, 20) to precipitate the Silicic Acid from the filtrate containing the soluble matters of the fluxed Iron, Alumina, &c., directly, by Carbonate of Ammonia. We do not think that this gives a reliable result, for even if the solution should be very dense the precipitated Silex would be in a gelatinous state, and consequently soluble in the water used for washing. Therefore, when the filtrate after neutralization by Hydrochloric Acid, is treated, according to Rose's directions, with Sulphate of Magnesia to precipitate triple Phosphate, a portion of Silica goes down with it. This fact was ascertained by digesting the ignited Ammonia-phosphate of Magnesia in Hydrochloric Acid, which left, in every essay, an insoluble residue of Silicic Acid. It was also observed that during this digestion a part of the Phosphoric Acid was volatilized, as free Magnesia existed in the solution. We sought to obviate these difficulties by evaporating the Phosphate filtrate to dryness before neutralizing the excess of Carbonate of Soda with Hydrochloric Acid, but we found it impossible to render all the Silica insoluble in this way, although

it prevented the volatilization of the Phosphoric Acid. We, therefore, neutralized the filtrate in its dilute state with Hydrochloric Acid, added a Nitric solution of a given weight of fine iron wire, and proceeded as already mentioned on the preceding page, and with the same unsatisfactory results.

Rose was the first to note that Phosphoric Acid was volatilized from Acid solutions of Phosphates by heat (*Chem. Gaz.*); and the confirmation of the fact by ourselves was soon after reaffirmed by some conclusive experiments by Bunce (*Silliman's Journal*, 1851), which show the loss to vary from 8 to 50 per cent. The process which we give at p. 420 is a slight modification of Otto's, and though not perfect, has the support of our experience in favor of its being the most reliable for these investigations. It differs favorably from others, in permitting the entire separation of Phosphoric Acid from Alumina as well as other associates, and also in requiring fewer digestions with Acids, and in prescribing a limitation of the temperature to 212° F., and thus preventing, as far as possible, any loss of Phosphoric Acid by volatilization. The only inconvenience attending it is burning off a large amount of Tartaric Acid and the separation of the Alumina from the excess of Magnesia added.

Fuchs has given a method (*Rose* 2, 438) by which the Silica, instead of reacting by fusion, is added to a Hydrochloric solution of the Oxide of iron, Alumina, and Phosphoric Acid in the state of liquid Silicate of Soda. Ulgreen (*Journ. Prakt. Chem.* 53, 37) amended it by substituting a mixture of Silicate of Soda and Sulphide of Potassium, so that the Iron may be precipitated as Sulphide, the Alumina as Silicate, and the Phosphoric Acid remains in solution with the Alkali. This is a very ingenious process, but it is no less tedious than Rose's, and is, moreover, equally objectionable in other respects, from a liability of loss of Phosphoric Acid and Alumina, owing to the repeated digestions required to isolate them from Silica, &c.

There is also a more recent method of the same chemist (*Chem. Gaz.* 1851), based upon the permanent solubility of the Ammonia-Phosphate of Magnesia in small quantities of Ammoniacal solution of Tartrate of Iron but not in Ferridcyanide of Potassium; Tartaric Acid and Cyanide of Potassium being the reagents employed. It may yield correct results, but it has no advantage over Otto's plan, as to time and easiness of execution.

Reynoso's method of separating Phosphoric Acid by Oxide of Tin (*Chem. Gaz.* 9, 418), appearing only to have been tried with an Alkaline Phosphate,

we have not thought it necessary to devote the time required to determine its applicability to an Aluminous compound, since we found Otto's plan better adapted to our purpose.

Tin and Titanium.

The filter *a*, which was set away in the early stage of the process, contains all the Silex and Slag, Tin and Titanium, with some Carbon. The Slag, Silex, and Carbons, having been determined in previous essays, it was reserved for the estimation of the two remaining components. A qualitative examination is only necessary generally, for in no one of our samples did we find even traces. Still they may occasionally exist, and must be sought, and if largely present, separated in the usual manner.

7th. If any Tin existed in the metal, it was converted into insoluble Stannic Acid by the oxidizing action of the nitric acid and subsequent evaporation, and remained with the insoluble residue. Its presence is proved by fusing the suspected insoluble residue on charcoal with carbonate of soda, grinding that part of the coal in an agate mortar with water and washing over with water until all the charcoal and other light particles have been removed, when Tin will betray itself by silvery spangles and streaks produced by the pestle.

8th. The presence of Titanium is best shown by fusing the whole residue with carbonate of soda, extracting with lukewarm water, filtering, partially neutralizing and boiling; *Titanic Acid* will precipitate. A yellowish tint in the soda solution will indicate the presence also of *Chrome*.

Arsenic, Antimony, and Sulphur.

As these components, if present, exist in quantities too minute to be estimated from one gramme of metal, a new portion of five grammes of clippings must be treated specially for the purpose.

9th. These are placed in a beaker of sixteen ounces capacity, and drenched with a fluid-ounce of pure nitric acid. The glass is covered with an inverted capsule, and very gradually heated to boiling by a small spirit lamp. As the digestion progresses, thirteen to fifteen grammes of finely powdered chlorate of potassa are added, portionwise, and the heat continued until the insoluble particles become flotant, when the digestion is completed. The nitric acid and chlorate of potassa, having eminent oxidizing powers, convert

most of the ingredients wholly into a soluble form. The metals being oxidized, their oxides dissolve in the acid; the Sulphur and Arsenic have become soluble Arseniate and Sulphate of potassa; and Carbon, Silex, and Slag remain as insoluble residue.

The liquor is evaporated to dryness to render Silica insoluble, redigested in hydrochloric acid to remove Oxide of Iron, &c., diluted with water, filtered, and hot washed. The filter is rejected, its contents having been already estimated in previous essays. The filtrate is *G*.

Aqua Regia cannot be substituted for the mixture of nitric acid and chlorate of potassa, for the amounts of Sulphur and Arsenic are so small that portions may be volatilized as gaseous hydrogen compounds. Nitric acid alone is slow in action, and the addition of *fuming* nitric acid to hasten its action, might introduce the very substances it is desired to detect, for that reagent is seldom pure.

If the size and distinctness of the Tache formed upon the porcelain, in the qualitative essay, indicated an appreciable quantity of Arsenic, the process must be continued as follows, to separate and estimate it quantitatively.

The filtrate *G*, contains all the ingredients in a soluble form, except those separated by the filter; but, owing to a large excess of Potassa Salt which is difficultly removed, is valuable only for the Sulphur and Arsenic. It is difficult to estimate Arsenic quantitatively by that modification of Marsch's process, in which the Arseniuretted hydrogen is reduced by heating the middle of the exit tube; for a portion of it may escape decomposition, and the black ring of Arsenic obtained in the tube, beyond the heated part, will only represent a fraction of it. It is true that Lassaigne's improvement, to conduct the excess of gas into a solution of Nitrate of Silver, recovers the whole of the Arsenic, but we believe that a modification of Reinsch's is a more effectual plan.

Strips of planished Copper are introduced into the heated filtrate *G*, until a fresh surface ceases to be tarnished. The strips are removed, rinsed in distilled water, and, when dried, carefully laid upon a sheet of glazed paper, and the tarnished coating entirely scraped off with a knife. The scrapings, carefully collected, are introduced into a long and narrow glass tube, and heated, to sublime the Arsenic as Arsenious Acid. The upper part of the tube containing the sublimate is then cut off, and, with its con-

tents, accurately weighed. The Arsenious Acid having been removed by hydrochloric acid and water, the empty tube is dried and again weighed. The difference in weight expresses the amount of Arsenious Acid in the filtrate, whence the metallic *Arsenic* is calculated.

A more critically accurate method would be to dissolve the scrapings into nitro-muriatic acid, and to estimate the Arsenic Acid from the filtered solution, by a given weight of metallic iron, as directed for Phosphorus.

10th. The only two substances in gun-metal precipitated by the metallic copper are Arsenic and Antimony, and as the two are frequently associated and give similar metallic stains, we thought it advisable in estimating one to test for the presence of the other. This was done by adding to the Tache, on the china, a concentrated solution of iodate of potassa, which, according to Slater, (*Chem. Gaz.*, ix. 57), reddens and immediately dissolves Arsenical stains, while upon those of Antimony it exerts no visible action for several hours. Chlorinated soda or lime will also instantly dissolve Arsenic and leave the *Antimony*.

11th. If the Tache did not indicate an appreciable quantity of Arsenic, the preceding manipulations may be omitted; otherwise, after it has been separated as above directed, chloride of barium is poured into the residual liquor, the whole stirred and left to repose for several days. If the content of Sulphur is very minute, cloudiness does not manifest itself for several hours, and in such cases a week's repose is necessary to insure its entire subsidence. It must then be filtered off and washed with diluted hydrochloric acid and hot water, ignited, weighed, and the amount of Sulphur calculated from the weight of sulphate of baryta.

It is proper to observe, in order to provide against the possibility of error, that some caution is requisite as to the nature of the precipitate, for if the solution be concentrated, a portion of the chloride of barium, which is generally added in excess, may ultimately fall in fine crystalline powder, but it will disappear during washing on the filter. The previous acidulation of the liquid prevents the precipitation of carbonate, phosphate or arseniate, of baryta.

Nitrogen, Oxygen, and Aridium.

The doubts of many of the best Chemists as to the presence of *Nitrogen* in Cast Iron having been confirmed by the recent experiments of a careful investigator, we omitted searching for it.

We doubt the presence of *Oxygen* as an essential ingredient of recently made metal, except in the minute portions of Slag accidentally remaining in it, and which sometimes contains a Silicate of the Oxide of Iron.

Aridium, said to have been found in some Swedish ores, was not observed by us in our examinations.

Respectfully submitted by

CAMPBELL MORFIT,

JAMES C. BOOTH.

Nitrogen, Oxygen, and Hydrogen.

The bodies of many of the best specimens of the presence of Nitrogen in Cast Iron being found to be the result of experiments of a kind of investigation we cannot describe here. It is about the presence of Nitrogen in the various portions of the metal, except in the minute portions of the surface, is not in it, and which sometimes contains a Silicate of the Oxide of Iron. Arden, said to have been found in some Swedish iron, was not observed by us in our examination.

Respectfully submitted by

CAMPBELL MORRIS

JAMES C. BOOTH



Reports of experiments on the strength and other properties of metals for
Cannon With a description of the machines for testing metals, and of the
classification of cannon in service

Philadelphia 1856

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